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FIELD TELEPHONES

FOR ARMY USE

INCLUDING AN ELEMENTARY COURSE IN ELECTRICITY AND MAGNETISM

BY

LIEUT. E. J. STEVENS, (D.O.) R.A.
A.M.I.E.E.

INSTRUCTOR IN ELECTRICITY, ORDNANCE COLLEGE, WOOLWICH

Capio Lumen

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PREFACE

THIS little book has been written with the object of meeting a need that has made itself felt in all branches of the Service, particularly since the Russo-Japanese war. The author has personally realised this need through the constant request from members of his classes for a book of notes on elementary theory and daily practice.

It has been his aim to include in this handbook the information that from his experience he knows to be really called for; and to explain the principles of Field Telephones both for commissioned and non-commissioned officers. It is hoped that those who have mastered the course of Electricity and Magnetism contained in the early chapters, will thoroughly understand the working of the various apparatus and readily appreciate the practical hints for field work.

The author's thanks are due to Mr. B. S. Cohen, A.M.I.E.E., who kindly corrected the manuscript, and to the International Electric Company and the British L.M. Ericsson Manufacturing Company for the loan of blocks.

E. J. S.

WOOLWICH,
June, 1908.

CONTENTS

FIELD TELEPHONES

CHAPTER I

BATTERIES

Simple Voltaic Cell

WHEN two different metals are placed in a solution which is capable of acting chemically on one of them, and joined

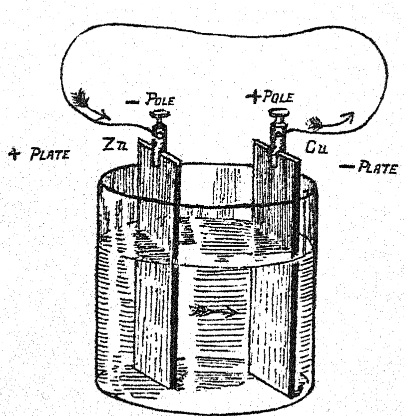


FIG. 1.

by a wire outside the liquid, a current of electricity is said to pass from one to the other inside the liquid, and back again by the outside wire, as shown in Fig. 1.

If the plates are zinc (Zn) and copper (Cu) and the cell contains dilute sulphuric acid (H_2SO_4), then the current is said to flow from the zinc to the copper plate through the liquid, and from the copper plate to the zinc by the wire outside the liquid.

The circuit is made up of the interior and exterior, the former being the portion of the plates immersed in the liquid itself, and the latter the portion of the plates outside the liquid and the connecting wire.

The energy of the current is derived from the dissolving of the zinc, and so long as there is zinc to be acted upon by the liquid a current can be generated.

The point or terminal at which the wire makes connection with the copper plate is termed the positive pole, and that point at which connection is made to the zinc is termed the negative pole.

The conventional way of showing a cell is as in Fig. 2,

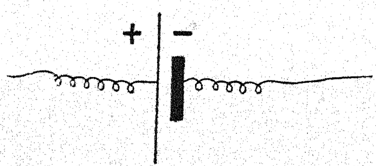


FIG. 2.

the zinc being represented by a short, thick line, and the copper by a longer and thinner line.

Defects

A simple cell of this description has two defects—local action and polarisation.

Local Action.—Commercial zinc being used for cells

is not pure, it contains impurities such as iron, arsenic, or other alloys, and as soon as the plate is immersed in a solution that will act chemically upon it, a local current is generated between the zinc and impure metal (Fig. 3); this eats away the zinc to no purpose and also weakens the main current.

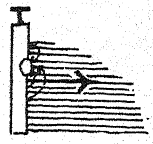


FIG. 3.

To overcome this the plate is amalgamated by first washing it in a weak solution of sulphuric acid, and, when clean, dipping it into or rubbing it over with mercury. The latter combines with the zinc, bringing pure zinc to the surface, thereby loosening the particles of foreign matter, which fall to the bottom of the cell. The mercury is not attacked by the acid, and continues to bring pure zinc to the surface, hence a surface of pure zinc is always offered to the liquid.

Polarisation.—The most troublesome defect is polarisation. This is a perceptible falling off in the current strength, and is caused by the bubbles of hydrogen gas, generated by the chemical action of the cell (when doing work), being deposited on the surface of the carbon or copper plate, whichever the cell contains. Gas is not a good conductor of electricity, and if allowed to accumulate will gradually cover the working surface of the plate, and therefore cause a falling off in current strength. The cell is then said to be polarised. This is practically overcome by using a substance rich in oxygen and placing it around the carbon or copper plate, either in a solid or liquid form; this is a "depolariser."

The most common forms are

Binoxide of manganese (MnO_2)
Copper sulphate ($CuSO_4$)

The depolarising action is due to the hydrogen combining

with the oxygen in depolariser; the result is, water (H_2O) is formed. If a cell is kept working for any length of time, although it contains a depolariser, it will still polarise a little.

This is due to hydrogen being generated at a greater rate than the oxygen in depolariser can account for it. To overcome this, break the circuit for a minute or so to allow the oxygen to do its work.

Leclanché Cells

The Leclanché Cell is the most common form of cell to be met with, and is largely used for house bells and stationary telephones, its great advantage being its cheapness. The ordinary form consists of a glass vessel of the shape shown in Fig. 4. This contains a zinc rod with a copper wire soldered to it, forming the negative pole, also a carbon plate with a lead head shrunk on to it for the attachment of the terminal or positive pole.

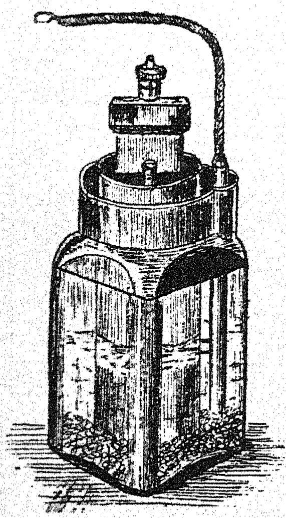


FIG. 4.

The carbon plate stands inside a porous pot, which contains the depolariser (binoxide of manganese) in a granulated form, mixed with granulated carbon to make it a better conductor. The porous pot is sealed. The glass vessel is nearly filled with a saturated solution of

salammoniac (NH_4Cl), which is the exciter. This gradually percolates through the porous pot, until the whole is left about three-fourths full.

The action of the cell is as follows :—

The zinc combines with the chlorine of the salammoniac to form zinc chloride ($ZnCl_2$), which is dissolved in the solution ; the hydrogen being set free from the salammoniac robs the depolariser of some of its oxygen to form water, ammonia being also given off, as shown in the chemical formula—

$$(1)\ Zn + 2NH_4Cl = ZnCl_2 + 2NH_3 + H_2$$
$$(2)\ H_2 + 2MnO_2 = Mn_2O_3 + H_2O$$

The Agglomerate Leclanché.—This differs from the type just described in having no porous pot, the depolariser being agglomerated with carbon and pressed into blocks. The blocks thus formed are held to the carbon plate by indiarubber bands, usually provided with small holes for the zinc rod, to keep the latter from touching the blocks. In other respects the cell is the same as the previous one. The advantage of the agglomerate type is, that, being without a porous pot, there is less resistance or obstruction to the current before reaching the carbon.

The glass vessels of the Leclanché cells and porous pots should always have their tops coated with black tar varnish or paraffin wax to prevent the creeping action of the solution, which, if allowed, would creep up to the lead head on carbon plate and cause a local action to take place between it and the carbon. This would form lead chloride (a white substance), which would get under the lead head, and as it is a bad conductor of electricity, would cause a bad contact to be made between the lead and carbon. The junction of lead head and carbon plate, and zinc rod and wire, should also be treated with this varnish.

Dry Cell

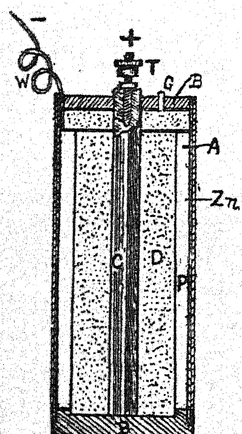
Dry cells have of late years come extensively into use. They are greatly used for telephonic purposes, and portable telephones owe their present state of perfection to the introduction of dry cells.

There are various makes to be found, such as the Obach, E.C.C., Hellesen, etc., which are all modifications of the Leclanché.

Obach Cell

There are various sizes of Obach Cells.

They consist of a zinc plate which is either cylindrical or rectangular in shape, in the centre of which stands a carbon rod; surrounding the carbon rod is the depolariser, made up in the form of a paste, consisting of binoxide of manganese, plumbago and gum. Between the zinc plate and the depolariser is the exciter, which consists of plaster of Paris and flour saturated with salammoniac; this paste is pressed down to ensure its coming in contact with the zinc, a disc of paper is placed on the top, above this a layer of sawdust which allows for expansion and also absorbs moisture, a second paper disc, and the whole is then sealed with pitch, a small glass tube being inserted to allow of the escape of gas that is generated.



A, cardboard case; *B*, sealing compound; *C*, carbon rod; *D*, depolariser; *G*, glass tube; *P*, exciter; *T*, terminal; *W*, copper wire; *Zn*, zinc cylinder.

FIG. 5.

A copper wire or a terminal soldered to the zinc forms the negative pole, and the terminal on the carbon stick the positive. The whole is inserted in a cardboard case, which entirely covers the zinc plate.

Arrangement of Cells

Generally speaking, cells may be arranged in two different ways.

When a battery consists of a number of cells, they may be arranged either in *series* or in *parallel*. To join cells in series (Fig. 6) the positive of one cell is connected to the

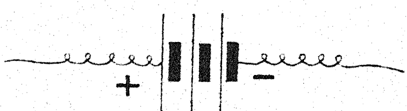


FIG. 6.

negative of the next, and so on. This leaves a free positive and negative, which are termed the poles of the battery.

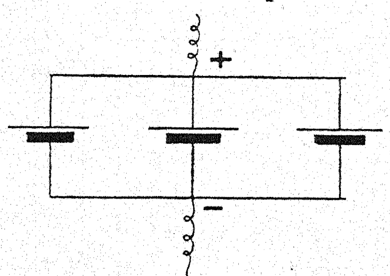


FIG. 7.

The plus sign denotes the positive, and the minus sign the negative pole of a battery.

To join cells in parallel (Fig. 7) all the positives

are joined together, and all the negatives in a similar manner.

The series method is nearly always employed. The advantage of this method is explained on p. 10.

Summary

Zn, Cu, H_2SO_4, NH_4Cl, etc., are the chemical equivalents for the plate or liquid. That is, H_2SO_4 means that sulphuric acid contains two parts of hydrogen, one of sulphur, and four of oxygen. From this example the others can be readily seen.

The electromotive force, or electrical pressure, depends upon the material used and not upon the size of plates. Hence all Leclanché cells give the same electrical pressure.

A saturated solution of salammoniac is obtained by dissolving crystals of, or powdered, salammoniac in water until no more will dissolve.

Hot water will dissolve salammoniac much quicker than cold.

Don't pour the solution into a cell until it is cold.

Don't fill a Leclanché cell full, especially one that is sealed, as the liquid level has a tendency to rise when the cell is working. This will encourage the lead head and terminal to be attacked if they come in contact with it.

Don't allow the terminals of a cell to get dirty; they should always be bright.

Agglomerate means a mixture; agglomerate blocks being a mixture of carbon and binoxide of manganese.

Cells may fail, due to—

Cause	*Remedy*
Insufficient solution.	Pour in more.
Weak solution.	Empty and add fresh solution.
Too much salammoniac being added to solution, causing the plates to be covered with crystals.	Scrape off crystals and add a little water.

Cause	*Remedy*
White deposit between lead cap and carbon, caused by creeping of solution or by splashing.	Replace carbon rod or plate by a new one.
Depolariser exhausted, indicated by cell running down when under test.	Replace depolariser.

The electromotive force or pressure of all Leclanché and dry cells is approximately 1·5 volt.

Dry cells should always be kept in a cool place.

Don't allow the positive and negative poles of a cell to touch, or connect them together with a short piece of wire, more especially a dry cell.

Cells are tested by means of an instrument called a voltmeter, which indicates the pressure or voltage of a cell when it is connected to it.

A terminal is a brass connecting-nut for attaching a wire to.

Some instruments have a terminal marked +. This means that the positive only of the cell or battery should be connected to it.

When a dry cell is exhausted it cannot be refilled.

Leclanché cells are very cheap.

The price of a quart size, porous pot form, complete, is about 1*s.* 2*d.*

The internal resistance of a quart porous pot Leclanché is about 1 ohm, and the agglomerate type 0·6 ohm.

Obach dry and Leclanché cells are made at *Siemens Bros.' Works, Charlton, London, S.E.*

In hot climates it is not desirable to have the salammoniac solution saturated.

Siebrosal, a specially prepared exciting salt, is prepared for use in Leclanché batteries in place of salammoniac. It

is considered better, and costs about 10*d.* a lb. tin. About 3 oz. is sufficient to make solution for a quart size cell. It can only be obtained from Siemens Bros.

Salammoniac can be bought in crystals or powdered. The latter is the best for cells. It is about 5*d.* a pound. About 7 oz. makes a saturated solution for a quart cell.

The price of an Obach dry cell, size P, is about 1*s.* 10*d.*; its dimensions being $2\frac{1}{4}$ in. square by $6\frac{1}{8}$ in. high; weight 2 lbs.

Obach cells are designated by letters.

Some Obach cells have a wire soldered on to the zinc plate instead of a terminal.

The Obach W size is specially adapted for use with motor cars and cycles as an ignition battery, price about 3*s.* each.

Don't carry an Obach dry cell with a negative wire connection by the wire. If you want to bend the wire, hold it firmly with one hand behind the point you wish to bend it from, and bend it with the other hand.

If the wire should break, cut the cardboard away a little at one side, and solder a fresh wire to the zinc plate.

Dry cells are not intended to be used on circuits that take more than 1 ampere; if so, only for short periods, as too much current would be taken from them, which would shorten their life.

A dry cell is practically useless for ordinary work when it gives less than 1 volt.

Cells should be joined in *series* when the external resistance is greater than the internal, and *vice versâ*, in *parallel*. This enables you to get as much current as possible out of the battery.

Example.—Find what current flows from the battery, when connected in *series*, and then in *parallel*, with an external resistance of 1st, 100 ω; 2nd, 1 ω. The battery consists of four cells, E.M.F. 1·5 volt, external resistance 1 ω each.

Work out after Chapter III. has been read.

CHAPTER II

ELECTRICAL CIRCUITS

Conductors

A CONDUCTOR is a substance that will convey or allow a current of electricity to pass freely through it. All metals are conductors, as also are some liquids, a few of the more metallic elements, such as carbon, and the earth.

Some metals will conduct better than others; that is, they vary in the obstruction which they offer to the current. Pure silver and copper offer the least obstruction of the metals.

The following are arranged according to their conducting power or conductivity :—

Pure silver	Platinoid
„ copper	Manganin
„ aluminium	Pure mercury
„ platinum	Carbon
„ iron	Dilute sulphuric acid (one-twelfth acid)
„ tin	Water
„ lead	The earth
German silver	

As copper is a good conductor, and being cheaper than silver, conducting wires are mostly made of it.

Insulators

An insulator is a substance that will not, under ordinary conditions, allow a current of electricity to pass through it. It therefore offers a great obstruction or resistance to the current, and is therefore the converse to a conductor.

The following are some insulators :—

Dry air	Earthenware
Ebonite	Glass
Indiarubber	Porcelain
Guttapercha	Black tar varnish
Paraffin wax	Paint
Dry cotton	Dry wood
Oiled silk	

Dry air is used as the insulator for uncovered telegraph wires, indiarubber being largely used for insulating electric light cables.

There is not a conductor that does not offer some resistance, neither is there an insulator that will entirely prevent a current from passing through it, if a very high pressure is applied. Under ordinary conditions, the pressure being small, the above insulators are considered perfect.

Resistance

The resistance of wires is found to depend upon the following :—

(*a*) Material of which it is made,
(*b*) Its length,
(*c*) Its diameter,
(*d*) Its temperature.

In the case of (*a*), a copper wire will conduct better

than one of iron; (*b*), it is proportional to its length; the longer the wire, the greater the resistance; (*c*) the thicker the wire, the smaller the resistance; (*d*) the resistance of metals increases with a rise of temperature, that of carbon and some liquids decrease.

The resistances of German silver, platinum, and manganin are practically unaffected by temperature.

Internal Resistance

The resistance of a cell is called internal resistance. The larger the plates, and the closer they are together, the smaller this resistance.

The Electric Circuit

The electric circuit consists of a battery, and the wires or instruments that may be connected between the poles, as in Fig. 8.

In the electric circuit there are three things to be considered.

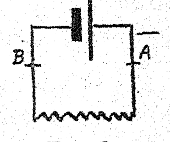


Fig. 8.

Firstly, let us remember that the wires and cell offer a resistance to the flow of current.

Secondly, there is the pressure that is generated by the chemical action of the cell, resulting in the flow of an electric current. This current cannot overcome the resistance that is offered to it unless it has a pressure.

Thirdly, the pressure that urges the current through the resistance, and which is known as the electromotive force (E.M.F.), is also obtained due to the chemical action of the cell.

The Electrolytic Cell

Let S, Fig. 8A, represent a piece of silver connected to the positive pole of a battery, and D a platinum dish containing a solution of silver nitrate, the negative pole of the battery being connected to the dish D.

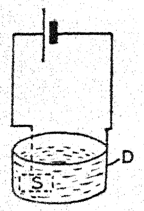


Fig. 8A.

When a current passes through the solution it decomposes it, causing it to obey the same law as the hydrogen and oxygen in the simple voltaic cell. In this case, the silver in the solution is deposited on the negative plate or dish D.

Current strength can be determined in this way, as the stronger the current the greater the deposit.

Units

In the ordinary affairs of life it is necessary to have units or standards of length, weight, time, etc., so also are units necessary for precise statement and calculation in electrical work.

The following are electrical units :—

Ampere.—The standard of current strength agreed upon is called the ampere, after a French scientist of that name. This current will cause a deposit of silver at the rate of 0·001118 gramme per second.

Ohm.—The practical unit of resistance is the ohm (called after Ohm, a German scientist), and is that amount of resistance offered by a column of pure mercury 106·3 centimetres long, and one square millimetre in cross section.

The ohm is usually denoted by the Greek letter ω (omega), thus 4 ω means 4 ohms.

Volt.—The practical unit of electromotive force is the volt (called after Volta, the Italian scientist), and is that amount of force that will enable one ampere of current to overcome the resistance of one ohm.

Conductance

The conducting power, or conductance, is the reverse of resistance. If a wire has a resistance of 4 ω, its conductance will be $\frac{1}{4}$.

The foregoing units were framed into a law by the German scientist Ohm, which he called Ohm's Law.

Ohm's Law

This states that the current flowing in a circuit is proportional to the electromotive force in volts, but is inversely proportional to the resistance in ohms.

That is $$C = \frac{\text{E.M.F.}}{R}$$

therefore $$R = \frac{\text{E.M.F.}}{C}$$

and $$\text{E.M.F.} = C \times R$$

By means of this law, if we know any two of the above, the third can be determined.

Example.—A Leclanché cell, E.M.F. 1·5 volt, internal resistance 0·2 ω, has connected to it a resistance of 4 ω. What current is passing in the circuit?

As you are asked to find the current, the formula to be used is—

$$C = \frac{\text{E.M.F.}}{R}$$

R, the total resistance in the circuit, will be the internal plus the external resistance.

Therefore $\quad C = \frac{1{\cdot}5}{4{\cdot}2} = 0{\cdot}35$ amp.

It will assist you if a sketch of the circuit is made as shown in Fig. 8.

In the above example, if we know the E.M.F. (1·5) and current (0·35 amp.), find the resistance that is being overcome.

The formula will be—

$$R = \frac{\text{E.M.F.}}{C} = \frac{1{\cdot}5}{0{\cdot}35} = 4{\cdot}2\ \omega$$

Example.—If in above example we know only the current (0·35 amp.) and the resistance (4·2 ω), find the E.M.F. that is being expended.

The formula will be—

$$\text{E.M.F.} = C \times R = 0{\cdot}35 \times 4{\cdot}2 = 1{\cdot}5 \text{ volt nearly.}$$

These examples prove that the formula $C = \frac{E}{R}$ can be modified to $R = \frac{E}{C}$, etc.

Resistances in Series and Parallel

Wires can be connected up either in series or parallel.

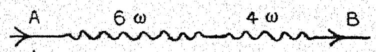


Fig. 9.

When they are joined in series, as shown, the resistance

which will have to be overcome by a current entering at A and leaving at B, or the joint resistance, will be—

$$6 + 4 = 10\,\omega$$

When the same two wires are joined in parallel, to determine the joint resistance, multiply the two together and divide by their sum, thus—

$$\frac{6 \times 4}{6 + 4} = \frac{24}{10} = 2{\cdot}4\,\omega$$

To determine the joint resistance of more than two unequal resistances in parallel.

Find the joint conductance by inverting the resistance

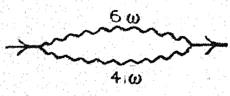


FIG. 10.

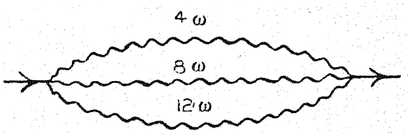


FIG. 11.

and adding them together, then invert the joint conductance, which will give the joint resistance—

$$\frac{1}{4} + \frac{1}{8} + \frac{1}{12} = \frac{6 + 3 + 2}{24} = \frac{11}{24} \text{ joint conductance}$$

$$\text{therefore the joint resistance} = \frac{24}{11} \text{ or } 2\frac{2}{11}\,\omega$$

To determine the joint resistance of any number of equal resistances in parallel, divide the resistance of one by the number in parallel—

$$\frac{20}{4} = 5\,\omega \text{ joint resistance}$$

or, in the case of cells of a similar type in parallel (Fig. 7):

If their internal resistance be $0{\cdot}25\ \omega$ and E.M.F. $1{\cdot}5$ volt each, then three cells connected in parallel would have a joint internal resistance of—

$$\frac{0{\cdot}25}{3} = 0{\cdot}08\ \omega$$

The E.M.F. of this combination would only be $1{\cdot}5$ volt, as they are acting as one cell with their plates increased threefold in size. This has the advantage of decreasing the joint internal resistance, and the disadvantage of only giving the voltage as for one cell.

As cells are hardly ever connected this way in the

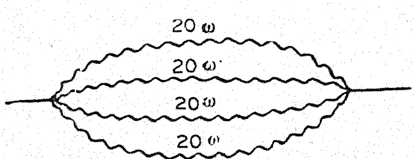


FIG. 12.

service, it will not be necessary to say any more here about it.

The reader will readily observe how much the joint resistance in a circuit can be reduced, if necessary, by joining the wires or resistance in parallel, thereby increasing the current.

Simple Circuit

In a simple circuit there is only one path for the current, therefore it is the same strength at any point of the circuit. In Fig. 8 the current at A will be the same strength as the current at B.

Compound Circuit

In a compound or parallel circuit, there is more than one path for the current to flow, as the resistances are in parallel. The path which has the smallest resistance will have the most current.

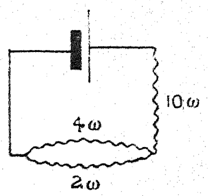


FIG. 13.

Metallic Circuit

A metallic circuit is one that is connected by a line and return wire.

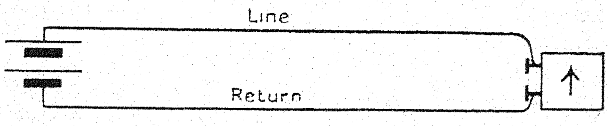


FIG. 14.

Earth Circuit

An earth circuit is one that utilises the earth instead of a return wire, an example being a field telephone or a telegraph circuit.

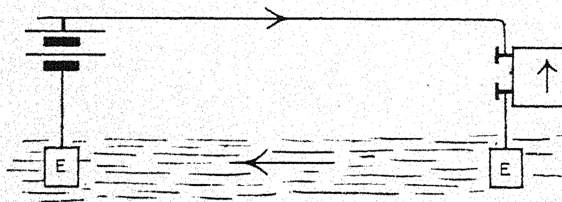


FIG. 15.

Short Circuit

A short circuit is caused by two wires making contact with each other, or the same piece of metal, thereby allowing the current to return without going to the instrument, as in Fig. 16.

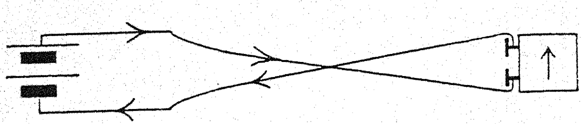


FIG. 16.

Summary

The ampere is the unit of current.
" volt " " " pressure or E.M.F.
" ohm " " " resistance.
The Metric System is used in electrical measurement—

1 metre	= 39·37 inches
1 centimetre	= 1 hundredth of a metre
1 millimetre	= 1 thousandth of a metre
1 milliampere	= 1 thousandth of an ampere
1 millivolt	= 1 thousandth of a volt
1 megohm	= 1 million ohms

Potential means the power of doing work.

Potential difference (P.D.) means the difference of power or pressure between any two parts of a circuit.

In a simple circuit, the current is the same strength at any point of the circuit.

In Fig. 13, the joint resistance of the circuit is found by working out the resistance of the 2 and 4 ω wires in parallel and then adding the result to the 10 ω, as the latter is in series with the joint resistance of the former.

German silver consists of four parts copper to one of zinc and two of nickel.

Platinoid consists of	59	per cent.	of	copper
	25·5	,,	,,	zinc
	14	,,	,,	nickel
	1·5	,,	,,	tungsten
Manganin consists of	84	per cent.	of	copper
	12	,,	,,	manganese
	4	,,	,,	nickel

CHAPTER III

MAGNETISM

Magnet

A MAGNET is anything that has the power of attracting or picking up pieces of iron or steel.

A lodestone is a certain hard black stone that is dug out of the earth, and will, if hung up from its middle by a thread, always set itself north and south. Such a stone was originally termed a "leading stone," from the fact that it was in early days used as a compass. It is an ore of iron, another name for it being magnetic oxide of iron.

If a bar of steel is rubbed with a lodestone, it will become magnetised, and if suspended will set itself north and south.

Steel bars or horseshoes treated in this way are termed artificial magnets, and are capable of attracting iron or steel.

Every magnet has two poles at which it will be found that the magnetic attraction is greatest. These are at the ends of a bar and horseshoe magnet.

We cannot obtain a magnet with only one pole; for instance, if a steel bar magnet is broken into several pieces, each piece will exhibit a north and south pole.

Artificial magnets may be either bar, horseshoe, or ring shaped, as in Fig. 17.

A compound magnet is made by clamping together thin

pieces of steel that have previously been magnetised, to form a single magnet. It may take the shape of any of the above. Such a magnet is stronger than a single piece of steel of the same size.

If a piece of thin steel is magnetised and pivoted horizontally on a pin point, it will, as previously stated, point north and south. A very common example of this is the ordinary pocket compass.

When the north pole of a bar magnet is presented to the north of a magnetic needle, it will be seen to be repelled. Such will also be the case if the south pole is presented to the south pole of needle.

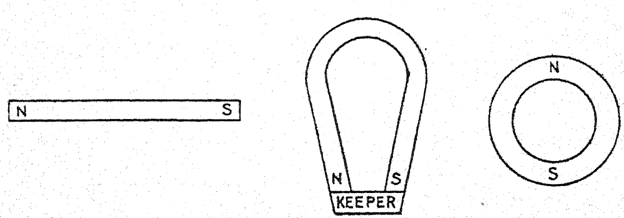


FIG. 17.

But if the north pole of magnet is presented to the south of needle, or south pole of magnet to north of needle, the needle will be attracted.

First Law of Magnetism.—The facts stated above may be summed up as follows: Like poles repel, unlike poles attract.

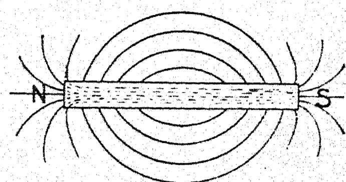


FIG. 18.

Magnetic Lines of Force.—It has been previously stated that artificial magnets have the power of attracting iron or steel; this is due to

invisible lines of magnetic force that are said to leave the north pole, curve through the air to the south pole, and along the body of the magnet as in Fig. 18.

To obtain a good magnetic figure of a bar or horseshoe magnet, lay the magnet flat down on the table and place over it a sheet of glass, on top of the glass place a sheet of paper, then sprinkle iron filings through a pepper-box evenly all over, gently tapping the glass at the same time. The filings will be seen to arrange themselves along the lines of force.

Fig. 19 represents two north poles placed opposite to

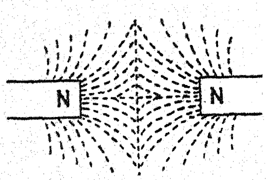


FIG. 19.

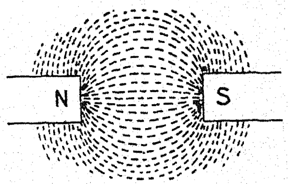


FIG. 20.

each other, and Fig. 20 a north pole placed opposite a south pole.

Magnetic Field.—The space surrounding a magnet through which the lines of force pass is termed the magnetic field.

Once steel is magnetised it retains its magnetism, but iron is only a magnet so long as it is in a magnetic field.

If a steel magnet is let fall, or is heated, it will lose some of its magnetism. It can be demagnetised by bringing it to a red heat and allowing it to cool slowly.

Residual Magnetism.—When iron has once been magnetised it retains a small amount of magnetism, which is called residual, more especially if the iron is not very soft. This is more noticeable in large pieces of iron.

Magnetic Induction.—In Fig. 21, opposite the north pole of the bar magnet is a piece of soft iron. It will be seen that some of the lines of force enter the iron, and in doing so the iron becomes magnetised, that end nearest the north of magnet will, of course, exhibit south polarity.

This is called magnetisation by induction, the north pole always inducing a south pole at the end of the iron nearest to it.

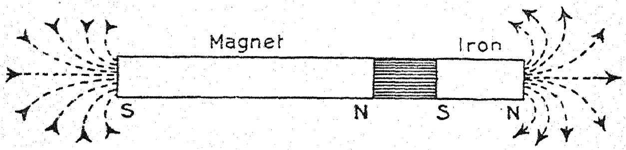


FIG. 21.

If the iron was near enough to the magnet it would be attracted to it and be magnetised, extending this pole as in Fig. 22.

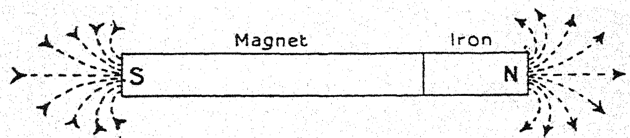


FIG. 22.

Magnetism of the Earth.—The reader will remember it was stated that if a magnetic needle was placed on a pivot, it would set itself towards the poles of the earth. This proves that the earth is a huge magnet, and gives out lines of force, which curve over its surface from pole to pole.

Besides the geographical north pole there is the magnetic north, which is, in Greenwich, about seventeen degrees west

of the geographical. It is to the magnetic north that a compass needle always points.

Summary

A lodestone is sometimes called magnetite.

In addition to steel and iron, nickel and cobalt are magnetic substances. Non-magnetic substances are silver, gold, brass, lead, etc.

Law of magnetic attraction and repulsion : Like poles repel, unlike poles attract.

The magnetism in a steel magnet is diminished, or perhaps destroyed, by rough handling or by extreme heat.

A pair of bar magnets should always be put away with unlike poles placed side by side, and an iron keeper across the poles. This enables the lines of force to go through the iron keeper instead of through the air ; the path being easier lengthens the lives of the magnets.

Never place a magnet near a delicate electrical instrument, or you may spoil the instrument.

A piece of steel may be magnetised by stroking it, from end to end, with one pole of a strong permanent magnet. The stroking must be always in the same direction, not backwards and forwards.

Electro-magnetism

If a wire carrying a current is held near a pivoted

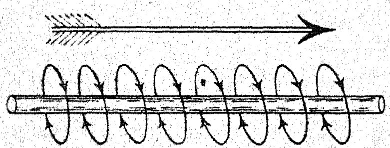


FIG. 23.

magnetic needle, the needle will be seen to be deflected.

This proves that the wire must give out lines of force, which act upon the needle. When a wire carries a current, whether it is insulated or not, it gives out circular lines of force throughout its length, as shown in Fig. 23. These lines of force disappear immediately the circuit is broken.

Next, let us consider the wire to be coiled, as in Fig. 24.

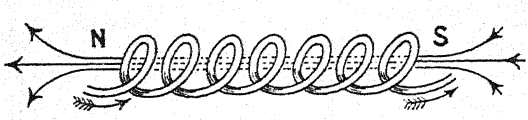


FIG. 24.

The field given out by the coil will be the same as a weak bar magnet, the ends exhibiting polarity.

If we insert a core of soft iron inside the coil, the iron will become strongly magnetised, due to the magnetic lines of force entering it, and the ends of the iron will exhibit polarity, as in Fig. 25. This is termed an electro-magnet.

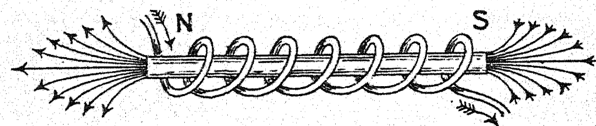


FIG. 25.

As soon as the current ceases to flow the iron becomes demagnetised, as the wire no longer gives out lines of force.

Electro-magnets are made in various shapes and sizes, the most common form being the horseshoe type, although the one shown in Fig. 26, not actually resembling a horseshoe, is called by this name.

The various parts of an electro-magnet are :—

B, B′ the bobbins of wire, C, C′ the cores of iron, being

joined at the bottom by the yoke of iron. The cores are usually made to screw into the yoke, an armature of soft iron, which is attracted when the cores are magnetised.

When a current passes, the ends of C, C′ become the poles of the electro-magnet, the lines of force passing from

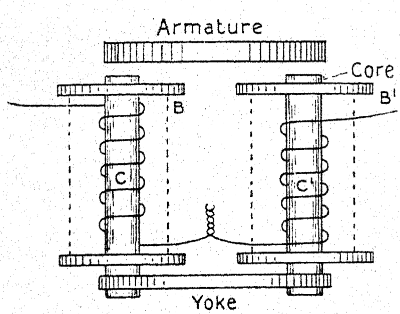


FIG. 26.

one pole to the other. If the armature is near enough it will be attracted to and held by the poles.

The electro-magnet is of great practical importance, and most electrical instruments are worked by this principle.

Trembling Bell

A very common application of the electro-magnet is in the ordinary electric bell. This, it will be seen, is caused to work by the magnetisation and demagnetisation of the electro-magnet.

In Fig. 27 T, T′ are the terminals of the bell, to which the wires from the battery are connected through a bell push; M is an ordinary electro-magnet, one end of the coil C being connected to the terminal T, and the other to the

metal or framework of the electro-magnet. A is an iron armature to which is fixed a piece of flat spring D, which acts as a pivot at E; a metal hammer screws into its other end. Opposite this hammer is placed a metal gong G; at the back of the armature is fixed a flat spring S, which is bent so that it will just touch an adjusting screw *p*. The adjusting screw passes through a pillar P, which passes through to the back of the board, where a wire is connected from it to the other terminal T′.

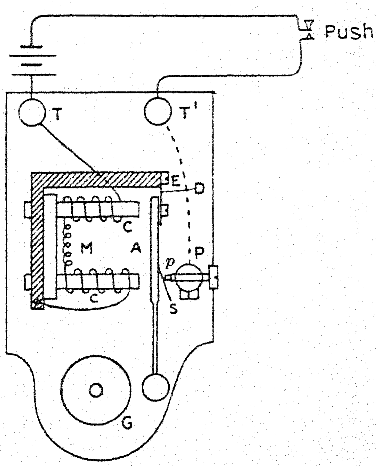


FIG. 27.

If the positive of a battery is joined to T, and the negative through a bell push to T′, the circuit will be as follows:—

From T around the electro-magnet coils (which are joined in series) to the frame, down the armature, from the flat spring S to adjusting screw *p*, to pillar P, back by the wire to terminal T′, through the bell push to the negative.

Action.—As the circuit has just been traced and is found to be complete, the current will cause the iron of electro-magnet to become magnetised, the armature is attracted by the poles, and causes the hammer to strike the gong. The armature brings with it the flat spring S, which leaves the screw *p*; this causes the circuit to be broken, and so demagnetises the electro-magnet, as no current is now passing. The magnet will therefore release the armature,

and allow the spring D to reassert itself and bring it back, as it was attracted against the pull of this spring. As soon as the spring S touches the screw *p* the circuit is again completed, and the same thing takes place. From this we can say that the bell is caused to ring due to the make and break of the circuit, causing magnetisation and demagnetisation of electro-magnet, and therefore attraction and release of armature.

Some bells have their coils wound on bobbins, and the bobbins slipped over the iron cores. The pole pieces are sometimes tipped with brass, to prevent the armature from sticking to them after the circuit is broken, due to residual magnetism.

To make it, or any trembling bell, act as a single-stroke bell, connect a wire from the frame to terminal T′. This cuts out or short circuits the adjusting screw, the circuit remaining closed when the armature is attracted, leaving the screw *p*, and is only broken by breaking the circuit at the bell push.

A buzzer is sometimes used instead of an electric bell. It differs from the bell in having no hammer and gong. The armature is much thinner, so that it will give a buzzing sound when it vibrates.

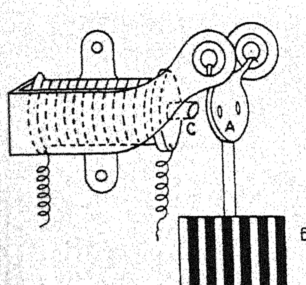


FIG. 28.

A common electro-magnet is used also in a simple relay, which is a form of electro-magnet, usually with a projecting piece on the armature, that will, when attracted, touch a contact and close another independent circuit.

This type of electro-magnet is called a common or non-polarised. In another shape it is used for a house indicator, as in Fig. 28.

The action of this type of indicator is that when a current passes round the coils, the iron core C becomes magnetised and attracts the iron armature A; as soon as the circuit is broken by releasing the bell push, the core C demagnetises and releases the armature; as this is loosely supported it will act like a pendulum and swing for some time, which is indicated by the painted portion B showing through the glass door of case.

Fig. 28A represents the circuits of a house wired with a four-room indicator, bell, and battery. It will be seen that

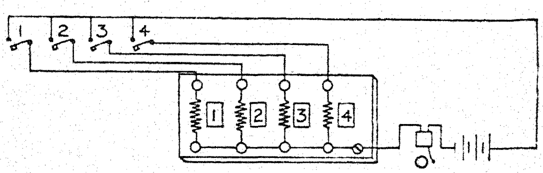


FIG. 28A.

when a push is pressed, that circuit is closed through its indicator, working it and also ringing the bell.

Polarised Electro-magnet.—A polarised electro-magnet is one that always has polarity, whether a current is passing or not. This is due to the presence of a permanent magnet.

Polarised Bell

The polarised or magneto bell consists of a] shaped permanent magnet M, on the south pole of which stands the yoke Y of an ordinary horseshoe-type electro-magnet, as in Fig. 29.

Under the north pole of the permanent magnet is an iron armature A, which is pivoted so that it can vibrate about its centre, just in front of the iron cores B. The hammer H is fixed to one side of the armature and moves with it, striking alternately the gong on either side.

The north pole of the magnet being over the centre of the armature A, makes it a magnet by induction, the middle having a south polarity, and the ends north. The yoke Y of the electro-magnet, standing on the south pole of the permanent magnet, has the effect of extending this south

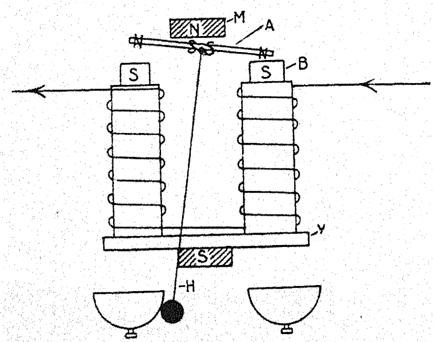


FIG. 29.

pole, as shown in Fig. 22, to the ends of the iron cores, which will exhibit a south polarity.

Action.—If a current enters the coils, say from the right side, it will have the effect of an ordinary common electro-magnet, that is, it will make one core a north, and the other a south pole. This effect will be to strengthen one core which has already a south pole, and weaken or neutralise the other core. The armature being attracted towards the left-side core, causing a blow to be struck on the right-side gong. If the current now enters by the

left side, the polarity due to the current will be reversed, causing the core that was previously strengthened to be weakened, and *vice versâ*, so that the armature will now be attracted by the right core, and the left gong struck.

It will now readily be seen that the current must alternately enter, first by the right and then the left side of coils, to make this type of bell ring. The current used is called an alternating current, and is generated by a small magneto generator, to be described later. Some bells have two polarising magnets, but their action is similar.

Galvanometer

A galvanometer or detector is an instrument that is used to detect the presence of an electric current.

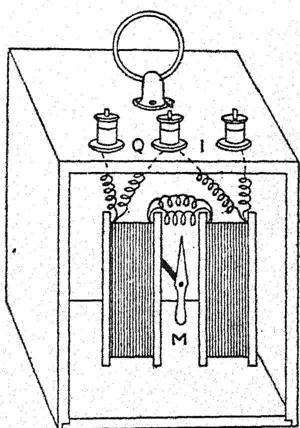


FIG. 30.

It has already been explained that a wire carrying a current gives out lines of magnetic force. It is on these that the action of a detector depends. If a coil of wire, as in Fig. 30, has pivoted inside it a magnetic needle M, when a current traverses the coil, the lines of force given out by it will act on the needle, and cause it to be deflected. Fixed to the same spindle, but at the other end of it, is a non-magnetic pointer that moves over a graduated scale. By this means the movement of the magnetic needle inside the coil is indicated on the scale.

Fig. 30 represents a linesman's detector. This is known in the service as Detector Quantity and Intensity. It has two coils and three terminals; between the centre and one other is fixed the letter Q, to these the ends of the low resistance coil are connected; resistance about 0·2 ohm. Between the centre and the other is fixed the letter I, to these the ends of the high resistance coil, about 100 ohms, are connected. The low resistance Q coil consists of a few turns of thick wire wound from one terminal round one bobbin, then on to the other bobbin, and back to the centre terminal. The other coil is wound in a similar manner, but, having a much higher resistance, consists of a greater number of turns. The high resistance coil is used with a high resistance circuit, and *vice versâ* the low resistance coil.

Summary

The reader will notice that the electro-magnet is by far the most useful electrical device, as nearly every instrument and machine depends for its action on it.

In winding an electro-magnet, if the coil comes off the core on the side nearest you, the winding on the other core should commence on the side farthest from you, as in Fig. 26, so that, if the cores were removed and put end on to each other, the winding would appear continuous.

To determine the polarity of an electro-magnet, a simple rule is as follows:—

Put down the letter S, mark the top part N, and the bottom S, thus $_{S}S^{N}$. This means that the top half of S being made in a *counter-clockwise* direction means north, and the bottom half being made *clockwise* means south. Therefore, if where the current enters an electro-magnet the winding takes a counter-clockwise direction, that end will have north polarity, and if it takes a clockwise direction it will be south.

Electro-magnets should be made of the softest iron, which is usually Swedish, well annealed after turning and filing has been finished.

The softer the iron the less chance it has of retaining magnetism.

The strength of an electro-magnet depends upon its ampere turns, *i.e.* the current passing through it multiplied by the number of turns of wire.

An electro-magnet that has to be used on a high resistance circuit (small current passing) should have a large number of turns of the wire on the coils (high resistance electro-magnet), as a weak current passing around the iron core a great many times will give a greater magnetic effect than a weak current passing around a few times, as would be the case if it were a low resistance electro-magnet. This also applies to the electric trembling bell.

If the circuit is a low resistance one, use a low resistance electro-magnet and a good battery.

Example.—If 3 amperes is sent around a coil having 20 turns, its strength will be $3 \times 20 = 60$ ampere turns.

Example.—If a current of $\frac{1}{5}$ of an ampere be sent round having 300 turns, its strength will be $\frac{1}{5}$ or $0{\cdot}2 \times 300 = 60$ ampere turns; that is, the same as the first.

It will be understood from this, why an electro-magnet intended for use with weak currents is wound with many turns of fine wire, and why one for large currents has only a few turns of thick wire.

An electro-magnet has the following advantages :—

It can be actuated from a distance.

It can be demagnetised by breaking the circuit.

Its polarity can be reversed by reversing the direction of current.

Its strength can be increased up to a certain point

(saturation) by increasing the current, or the number of turns of wire on its cores.

Saturation means that a piece of iron can only be magnetised up to a certain strength, which depends upon the kind of iron, and its size.

Magnetic lines of force cannot be insulated, therefore it is immaterial whether the coils of an electro-magnet are wound directly on to the iron, or on to a bobbin, and then slipped over the iron. For convenience the latter method is usually employed.

A trembling or chattering bell often fails to act, due to the want of adjustment of the contact or adjusting screw.

A small screw is often to be seen on the side of the adjusting screw pillar. This is for clamping after it has been adjusted. Never try to adjust without loosening the clamping screw.

If a trembling bell becomes an annoyance, make it a single stroke as previously explained.

The resistance of the two coils of some first grade trembling bells is about 100 ohms.

The points of contact between spring at back of bell armature and the end of the adjusting screw should be tipped with platinum, if not, the metal gets burnt away due to the spark caused by the break of the circuit at this point. This would cause a faulty contact here.

All contact keys should be tipped with platinum; it prevents this.

Some electric bells have the electro-magnet and armature combined under the gong. The electro-magnet in this form is not a horseshoe, but a single coil and iron core.

Electric indicators are either pendulum or replacement.

The pendulum is set swinging by being attracted

when the bell is rung, as the indicator magnet is in series with it.

In the replacement type the armature of indicator is attracted, and allows the indicator to fall. It has to be replaced mechanically.

There is an electrical replacement indicator which has to be replaced by pressing a push-button (usually fixed underneath) when the indicator falls; a relay is used with it.

Replacement indicators have the disadvantage of the attendants forgetting to replace them, causing extra wear on the stair carpet when they go to see where they are required.

A 6-hole pendulum indicator costs about 9*s*. (without bell).

A 6-hole replacement indicator costs about 12*s*. 6*d*. (without bell). Electric bells range from 1*s*. 9*d*. to about 21*s*. *Veritys, Ltd., King Street, Covent Garden, W.C.*

To ascertain by means of a detector if a wire or circuit is broken, place the detector in series with the circuit at any point; a deflection will be obtained if correct.

In testing a house-bell circuit for continuity, connect it in series, and close circuit by pressing bell push. This should give a deflection.

A bell push is usually a circular piece of wood, metal, or china, that contains two strips of metal to which the two wires of a bell circuit are connected. They are made to touch and complete the circuit by pressing a button on the face of the push.

The best sort of bell wire to use for ordinary house wiring is a number 20 or 22 S.W.G. plaited twin, and insulated with paraffin waxed cotton.

The wires should be coloured differently.

When stapling such a wire, always insert one leg of the staple between the wires. If the two wires are placed between the legs of staple, and the latter is driven home too far, it usually penetrates the insulation, causing a short circuit and a great deal of time to be wasted in locating.

CHAPTER IV

INDUCTION

The induced current forms a very prominent part in the theory of modern electrical apparatus.

Magnetic Induction

It is best understood by means of a few practical experiments.

In Fig. 31, B is a hollow bobbin on which is wound cotton-covered copper wire. The inner and outer ends of the wire are connected respectively to the two binding screws. NS is a permanent magnet, G is a galvanometer, or current detector, which is connected in series with the coil by means of wires about a yard long, so as not to be too near the coil, and cause the magnet to affect it.

If now we plunge the magnet inside the coil north pole first, the galvanometer will be seen to deflect. When the needle comes to rest, withdraw the magnet rapidly; this will cause it to be deflected in the opposite direction. It will now be apparent that a current of electricity is induced in the coil, due to the lines of force given out by the magnet cutting it. This is called an induced current.

Repeat the experiment with the magnet south pole first; the direction of current will be reversed in each case.

If the magnet is moved about, either in or near the coil, the galvanometer will be affected. The same effect

will be observed if the magnet is stationary and the coil moved about. It must be remembered that it is only when there is a movement between the lines of force and the coil that we get an induced current.

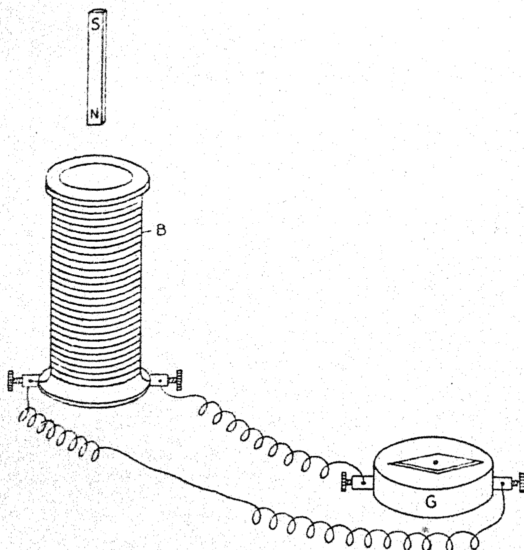


FIG. 31.

Electro-magnetic Induction

Let the bar magnet now be replaced by a coil P (Fig. 32), with a core of soft iron. Connected in series with it, is a battery and simple key. Place P inside the coil B.

If now the key be pressed a current will flow round the coil P, and will magnetise the iron core. The lines of force

which shoot out from the iron will, in their passage, cut the coil of wire B causing a current to be induced in it, which will be indicated by the galvanometer needle deflecting. If the current is kept flowing in the inside coil, the induced current will cease to flow and the needle come to rest, owing to there being no movement between the lines of force and coil. Now break the circuit at the key; this will give another kick in the galvanometer in the opposite direction to that when the key was pressed, due to the

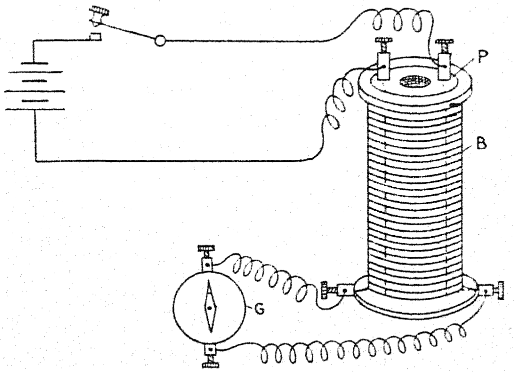


FIG. 32.

iron being magnetised. The lines of force this time, being withdrawn, cut the coil B in the opposite direction to when they were shot out.

If when the current in the coil P is once started its strength be either increased or decreased, each alteration will cause an alteration in the strength of the magnetic field, and any disturbance in the magnetic field will cause the wires of the coil B to be cut by the lines of force, thereby inducing a current in the latter.

It will now be seen that when the current is started in P, an induced current is obtained in one direction, and when it is stopped the induced current is in the opposite direction.

The current in the coil B is therefore an alternating current; that is, one that keeps changing its direction, and is induced in it if the circuit in P is made or broken, or if the current strength in P is altered as explained.

Induction Coil

Such an apparatus as shown in Fig. 32 is called an induction coil. It consists of two coils, the inside coil P is called the primary coil, and consists of a few turns of low resistance (large gauge) copper wire wound round a soft iron core, outside of this is the coil B, called the secondary coil, which consists of a great many more turns of high resistance (small gauge) copper wire.

The function of the induction coil is to transform a large current with a small pressure, into a small current with a large pressure. This means that if a current of say 5 amperes, with a pressure of 2 volts, was applied to the primary coil, the induced alternating current in the secondary coil might be something like 0·002 ampere, with a pressure of thousands of volts.

A rough rule for calculating the induced volts in the secondary coil is, that it is in proportion to the number of turns in the primary to the number in the secondary coil.

This means, for a coil having 100 turns in the primary and 10,000 in the secondary, for every volt applied to the primary coil, there will be induced in the secondary 100 volts, as the ratio of the windings is 1 to 100.

The induction coil plays a very prominent part in the

modern telephone, of which more will be said later. It also has many other applications, some of them being for X-ray work, wireless telegraphy, ignition purposes in motor cars and cycles, etc. The latter application being used by so many at the present time, I think a few words about a simple form of ignition will not be out of place here, and might benefit those who are interested.

In a motor car or cycle the primary coil is joined in series with a two-cell battery, and a contact cam that is

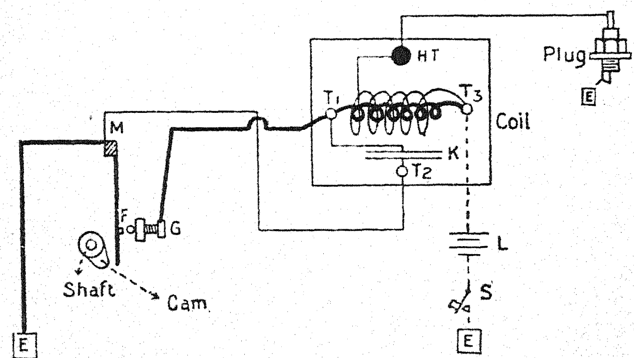


FIG. 33.

made to close the circuit by a rotating part of the engine, as in Fig. 33.

The rotating cam causes a momentary contact to be made in the primary circuit, which, as previously explained, will give a momentary induced current in the secondary coil. One end of the secondary coil is connected by an insulated wire to the sparking plug, which screws into the back of the combustion chamber, the other end of the secondary is usually common to one end of the primary coil, and this is, as shown in Fig. 33, connected to the battery,

then through a switch S, and earthed; or, in other words, connected by a wire to the metal of engine under any convenient nut. Some primary circuits are earthed, as in Fig. 33.

Circuit.—The shaft, with cam attachment, is caused to rotate by the engine, which makes it complete the primary circuit at point FG, when the piston has just completed its compression stroke. This momentary contact will allow a current to flow from the battery, through the primary circuit, which will induce a momentary current in the secondary coil, leaving by HT, and flow to sparking plug, jump the air gap between the pins at end of plug to earth, through the switch S (which would be closed), and back to secondary coil at T_3.

The spark in the secondary circuit takes place across the sparking plug, igniting the petrol vapour, which forces the engine piston out.

The primary circuit is shown in thick lines, the secondary in thin, and that part common to both circuits dotted.

A modern form of induction coil is shown in Fig. 34. It is fitted with an automatic make-and-break device, which acts like the armature of a trembling bell, and is usually called an interrupter. Its functions are to make and break the circuit, so as to obtain the induced alternating current in the secondary coil. This is caused by a piece of iron on the interrupter being attracted by the end of the iron core which it is placed opposite to.

Condenser

In Fig. 34 a condenser will be seen connected between the two parts of the interrupter that make and break the

circuit. It consists of several sheets of tinfoil separated by sheets of paraffin wax or paraffined paper. Alternate strips of foil are connected together, so that they practically form two big sheets. A coil not fitted with a condenser will be seen to spark badly on the break of the circuit at the interrupter, which will in time fuze the platinum points. Another disadvantage is, that so long as the spark lasts

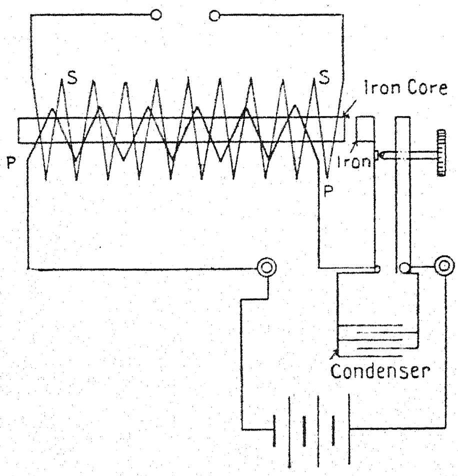


FIG. 34.

some current must be passing, hence the current falls off gradually instead of sharply, this means a falling-off in the E.M.F. induced in the secondary, as this depends on the rate at which the lines of force disappear from the circuit. To prevent this, the condenser is connected as shown.

Action of Condenser.—The current at break, instead of sparking across the contacts, rushes suddenly into the condenser and charges one set of plates with a positive

charge of statical or stationary electricity, the other plates having at the same time an equal negative charge. This, therefore, enables the primary current to stop quickly; but it does more than this; no sooner is the condenser charged than it discharges itself through the primary, sending a reverse current through it, and so further strengthening the E.M.F. induced in the secondary.

Magneto Generator

The magneto generator with polarised bell, is almost exclusively used for signalling purposes with modern telephones. It has the advantage of being self-contained, and more reliable than the bell operated by a battery, and will work through lines of high resistance, which would require a large battery if worked by a trembling bell.

It consists of several permanent horseshoe magnets M, held together by pole pieces of iron P, P′, which are fixed by screws, as shown in Fig. 35. This has the effect of concentrating the lines of force across the pole pieces, making them act as a single magnet. Fitting between the pole pieces, with just sufficient space to allow it to revolve freely, is the armature, which consists of an iron shuttle, S, wound with many turns of thin copper wire, one end of the winding being connected, as in Fig. 35, to a pin, A, fixed to the metal of the shuttle, the other end is connected to a pin which passes into the shuttle through an ebonite tube until it reaches another pin, B, which is also insulated from the metal of the shuttle. This means that one end of the coil is common to the metal, and the other is insulated from it. On the other end of the spindle is fixed a toothed pinion, which gears into a toothed wheel about five times its diameter, fixed to the spindle that carries the rotating

handle. When the handle rotates, the armature makes about five revolutions to one of the handle.

Action.—It has already been explained that when a coil of wire cuts lines of force, a current will be induced in the coil. If the armature is caused to rotate by turning the handle of the generator, it will move in a powerful magnetic field, as it is between the poles of the magnets, causing a current to be induced in the armature coils. The relative direction in which the lines of force

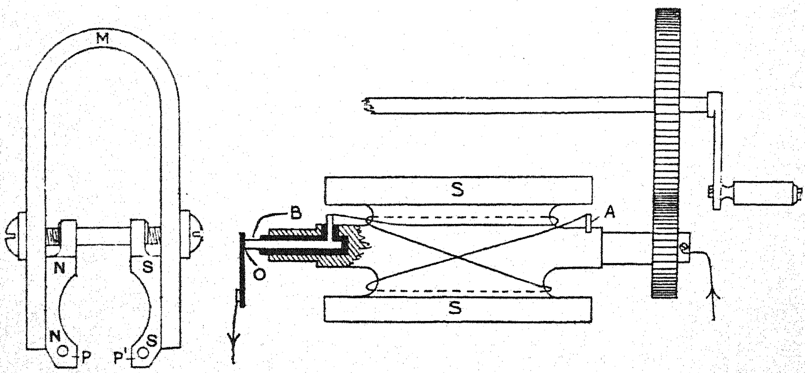


FIG. 35.

pass through the coil is reversed with each half-revolution, and therefore a complete revolution of the armature will cause two currents to be induced, alternating in direction. This current is conveyed from the armature by a wire being connected to the metal of the generator at any convenient point, and a rubbing contact being made by a piece of metal with the insulated end of armature at the point O. In the figure the armature is shown to a larger scale than the magnet to make it clearer.

This type of generator is always employed with a polarised bell (Fig. 29), and is usually connected in series with it, so that when the distant station is being called up the home bell will ring also.

Automatic Cut-Out.—When the home station is being called up, the current passing round the bell coils would also go through the armature windings, and as the resistance of some armatures are wound to 500 ohms, this would greatly reduce the current through the bell coils. To prevent this, automatic cut-outs are fixed to some generators to short circuit the armature when the handle is not turned, and allow the current to pass through the metal of generator instead.

Summary

An induced current is one that is caused by lines of force cutting a coil of wire. Sometimes the coil is stationary and the magnets are caused to move. An induction coil used in a telephone does not have an interrupter.

The induced current in the secondary of an induction coil is alternating. When the circuit is completed in the primary, it flows in one direction, and when it is broken, it flows in the opposite.

The iron core of an induction coil is usually made up of a bundle of iron wires. A core of this kind magnetises and demagnetises more readily than a solid core. It is termed a laminated core.

The primary coil has a low, and the secondary coil a high resistance.

An induction coil is usually rated by the length of spark that can be obtained from the ends of the secondary coil. Coils used for X-ray work usually give from 6 to 10 in. spark. Those used for wireless telegraphy are required to give a longer spark.

The platinum points of a coil interrupter require occasional attention. They get burnt away and require touching up lightly with a smooth file. Platinum is very expensive.

An induced current in the secondary can only be obtained by making and breaking the primary circuit, or by varying the current strength in it.

The greater the number of interruptions per second, the greater the induced E.M.F. Some large induction coils have separate interrupters that are driven by a small electric motor.

A good induction coil for ordinary telephone work has the following dimensions:—

Primary coil resistance 0·5 ohm, 180 turns of 24 mils. diameter (23 S.W.G.). Secondary wire, resistance 420 ohms with 4200 turns of wire 6 mils. diameter.

A mil. is equal to a thousandth of an inch.

A common form of telephone induction coil to be met with has a primary coil resistance of 1·5 ohm, and a secondary coil resistance of 25 ohms.

An interrupter is sometimes called a vibrator.

A small condenser is usually connected between the contact points of an interrupter.

A condenser is not required with an induction coil without an interrupter, such as a telephone induction coil.

A magneto generator used with a telephone generates from 50 to 70 volts, sometimes more.

Magneto generators are used in most of the modern telephones. They generate an alternating current, and are used for ringing a polarised bell.

A rough test for a magneto generator, is to place one finger on metal of generator and another on the insulated point of the armature; on turning the handle of the generator a slight shock should be felt, if correct.

CHAPTER V

MICROPHONES AND RECEIVERS

HAVING perused the foregoing chapters, the reader will find himself in a position to understand the working of a telephone.

Bell Telephone

The credit for the invention of the telephone is generally given to Professor Bell. Fig. 36 shows a section of a Bell telephone. It consists of a permanent magnet, NS, having fixed to N a pole piece of soft iron, around which is wound

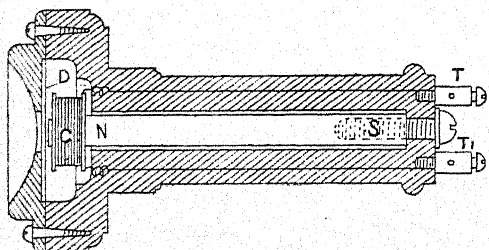


FIG. 36.

a coil of wire, C, the ends of the coil being brought to the two terminals, T, T_1. Opposite to the soft iron pole piece is placed an iron disc, D, held in position by the case, so as to be just clear of the pole piece.

Action.—This instrument was used to speak into, and to hear with; that is, it was a transmitter and receiver combined. Let us consider two of these instruments connected up, as in Fig. 37, by means of a line and return wire.

If a person at A speaks into his telephone, the sound waves given off by the voice will impinge upon the disc, and cause it to vibrate. The vibrations of the disc will cause a disturbance in the lines of force given out by the iron pole piece; this disturbance in the magnetic field will give rise to an induced current in the coil C, as the lines of

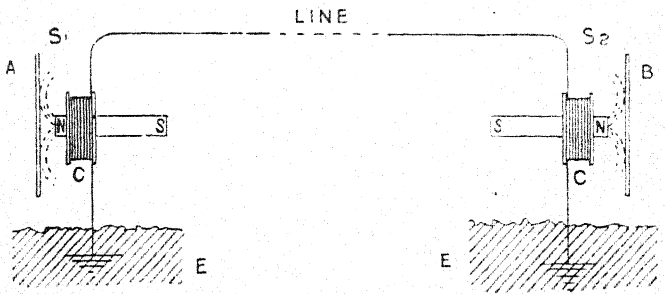


FIG. 37.

force continually being altered will cut this coil. The induced current is alternating, being in one direction when the disc moves backward, and in the opposite when it moves forward. It is conveyed by the line wire to the distant telephone B, passing round the coil C at that end, and back by the earth. This current either increases or decreases the strength of the magnetic field of the pole piece at B, according to its direction, which means that the disc at this end is pulled by a variable force, causing it to vibrate and give off air waves, which are converted into sounds by the ear of the listener.

The vibrations of the disc at B can be said to copy those at A, which are caused by speaking to the disc.

Hughes' Microphone

An improvement on the above was made by the introduction of a separate transmitting instrument and battery into the circuit, using the Bell telephone as a receiver only, as in Fig. 38.

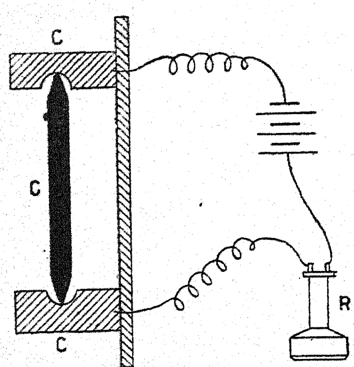


FIG. 38.

This transmitter, or microphone as it is usually called, consisted of a carbon pencil loosely held between two carbon supports, the whole being mounted on a thin deal sounding board, and joined in series with a battery and Bell receiver.

Action.—On talking to the sounding board, the sound waves acting on it, cause the loosely held carbon to vibrate in its supports, this upsets the steady current that would otherwise be flowing round the circuit, as the carbon sets up a variable resistance, causing a variable current to flow through the receiver. This variable current passing round the receiver coil, will result in a variable magnetic field, which will cause the disc to vibrate, these vibrations being converted into sounds by the ear of the listener.

The power of the telephone was further augmented, especially when used over long distances, by Edison, who introduced the induction coil into the circuit.

The microphone and battery were connected in series with the primary of the induction coil, and the line wires,

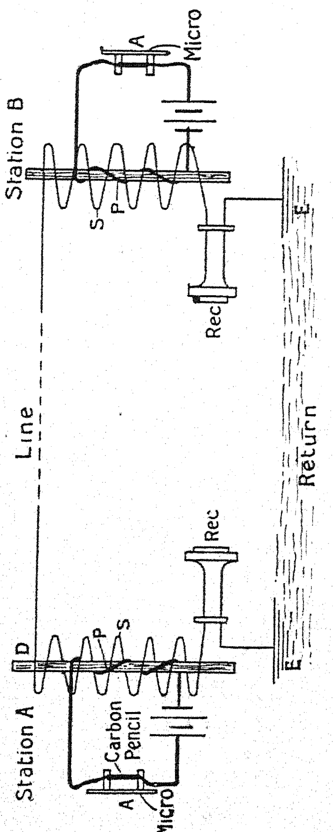


FIG. 39.

or line and earth, were joined in series with the secondary coil and receiver at each end, as shown in Fig. 39.

Action.—On talking into the microphone at station A,

the carbon vibrates, causing a variable resistance in the circuit, which gives rise to a variable current. As the current passes through the primary of induction coil, which has a core of iron, a variable magnetic field is given out by it, which will cut the secondary coil, inducing a current in it.

This induced current is alternating, and, as there are more turns in the secondary than in the primary, as explained on p. 42, it is a small current of high voltage, or potential, and leaves the coil say at D, goes by the line wire to the far station B, through the secondary coil and receiver, returning by earth through the home receiver, and back to where it started from. The alternating induced current passing through the receiver coil at B, sets the disc vibrating; these vibrations are converted into sounds by the ear of the listener. A similar action takes place when the microphone at B is spoken to.

It will be seen that the microphone, or primary circuit, as it is usually called, is a local circuit; the secondary circuit is common to both ends, through the line wires.

The circuits as explained above, represent the speaking circuits of a modern telephone, with the exception that a wire is sometimes employed as a return, and not the earth.

An advantage of the induction coil in a telephone is, that the induced secondary current, being of high voltage, will urge the small current through a very large line resistance to the distant station receiver, and as a receiver only requires a very small current to actuate its disc, this current is large enough to answer the purpose, hence the introduction of long-distance telephony. Also the percentage variation increases when a coil with low resistance primary is used.

Before proceeding further with the telephone, it will be advisable to investigate some of the modern microphones and receivers.

Microphones

Microphones can be divided into two classes, viz. (1) the Pencil Carbon and (2) the Granulated Carbon.

Pencil Microphone.—There are many types of pencil microphones to be met with, such as the Hughes, Gower, Ader, etc.

A very common form is the Ader. This is shown in Fig. 40, and consists of three carbon supports, B, between which are loosely held twelve carbon pencils, C. By

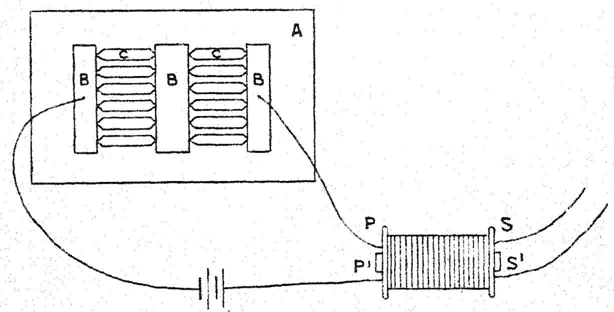


FIG. 40.

increasing the number of pencils, and joining them up in parallel in this way, the resistance is reduced and disagreeable sounds due to jars are lessened.

The carbon pencils are usually mounted on a thin pine sounding board, A.

The microphone in Fig. 40 is shown connected up to a two-cell battery and primary P, P′, of an induction coil. S, S′, are the ends of the secondary coil. This type of microphone has been extensively used in France.

Granulated Carbon Microphone.—These are the

most powerful type of transmitter, and their introduction has added greatly to the success of long-distance telephony.

The Solid Back.—This type of microphone was invented by a Mr. A. C. White, of America, and is considered very successful, being extensively used with some of the present-day telephones for desk use and those fixed to the wall.

It is shown in section in Fig. 41, and consists of a brass cell, A, with a screw cover, B, which clamps a small flexible

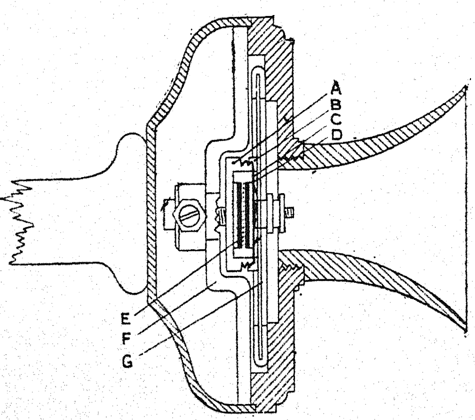


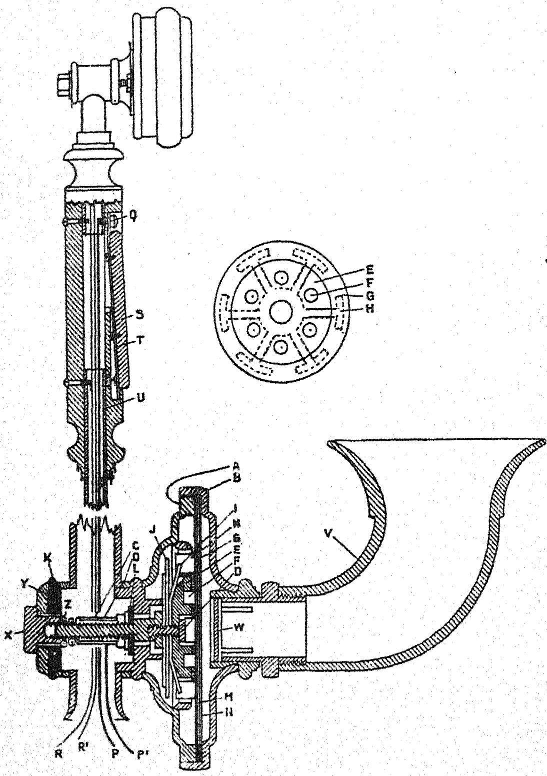
FIG. 41.

mica disc, C, on the face of which is fixed a thin carbon plate, D, which is a little smaller than the inside of the brass cell. Opposite to this is fixed another carbon plate, E. The brass cell is rigidly fixed to the bridge piece F by a screw. The mica disc is clamped by a screw to a large aluminium disc, G, fitted with indiarubber round its edges, and held in position by two flat steel springs (not shown), which are fastened to the casing. The space between the carbon plates D, E is filled with granulated carbon.

This type of microphone is said to be free from "packing," that is, the gradual settling down and consolidating of the carbon granules, making it act as an ordinary solid carbon conductor, instead of the loose contact upon which its sensitiveness depends. It is usually fixed to a moving arm for adjusting to the height of the operator. Its resistance is from 20 to 60 ohms.

The Ericsson.—This is considered to be a very successful microphone, and is extensively used in the service. It is usually fixed to a combined hand micro-receiver, as in Fig. 42. A description of the receiver portion will be given later. There are several forms to be met with, but Fig. 42 gives a sectional view of the latest. A and B comprise the aluminium case, which is made in two parts; passing into the back of the case A is a small steel bolt, C, the head of which has screwed into it the brass screw D, which holds in position a carbon block, E, that is recessed for the reception of the screw. The front face of this block has several holes drilled in it, into which tufts of felt, F, are fitted. When in position these tufts press against a carbon disc, G. A sleeve of soft felt, H, is fitted around the edge of the carbon block, and is made to press against the carbon disc by the heads of six bronze springs, I, which are all joined together at the centre, as shown in Fig. 42, which shows an end elevation of the carbon block. This spring fits into six recesses in the carbon block, which allows it to work freely.

The carbon block and springs are insulated from the frame A by the celluloid washers J, and the steel bolt C by an ebonite washer, K, at one end, and a leather washer, L, at the other. Rings of blotting paper, M, are used to clamp the carbon disc; they also hold in position a piece of oiled silk, N, which prevents moisture of the breath reaching the carbon disc. About five grains of granulated carbon



A Aluminium case
B Aluminium case
C Steel bolt
D Brass screw
E Carbon block
F Felt tufts
G Carbon disc
H Felt sleeve
I Bronze star springs
J Celluloid washers
K Ebonite washer
L Leather washer
M Paper rings
N Oiled silk
O Contact for wire
PP' Primary wires
Q Pressel switch pivot
RR' Receiver wires
S Pressel switch
T Metal strip
U Metal frame
V Celluloid mouthpiece
W Wire gauze
X Sleeve nut
Y Metal washer
Z Spiral spring

FIG. 42.

are held in the recess between the back of the disc and the face of the carbon block.

The normal resistance of this microphone is about 100 ohms, and when working varies between 50 and 160 ohms.

It will be seen that there are four wires coming from it, two, R, R′, are from the receiver, which would be connected to the secondary circuit of the telephone, and two, P, P′, from the microphone to the primary circuit. The wire P′ is connected to the steel bolt at O, and P to the pivot Q of a pressel switch, S; this switch has a strip of metal, T, extending throughout its length. U is the metal framework.

Circuit.—The microphone would be joined in series with a two-cell battery, and the primary of induction coil; therefore the current would enter by, let us say, P′, and flow through C, D, E, G to the metal frame; the pressel switch S being pressed, it gets to T, Q, the wire P, and back through the other part of the primary circuit.

From this it will be seen that if a microphone has a pressel switch, it must always be pressed when speaking into it.

The microphone is shown enlarged for clearness.

Action.—When a current is passing through the microphone, if the mouthpiece is spoken into, the sound waves of the voice striking the carbon disc will cause it to vibrate, this will disturb the carbon granules, causing a variable resistance to be set up, which will vary the current in the circuit and give an induced current in the secondary coil, as was explained when talking to the pencil microphone on p. 54.

This type of microphone is very sensitive, hence its use with the majority of modern telephones.

The Hand Micro-telephone is very extensively used in

this country. It allows the user to adopt any convenient position, and as the primary circuit passes through the pressel switch, which is automatically broken as soon as it is released, this circuit is independent of the automatic switch hook or cradle. They are usually constructed of ebonite and aluminium, and are therefore very little heavier than an ordinary receiver.

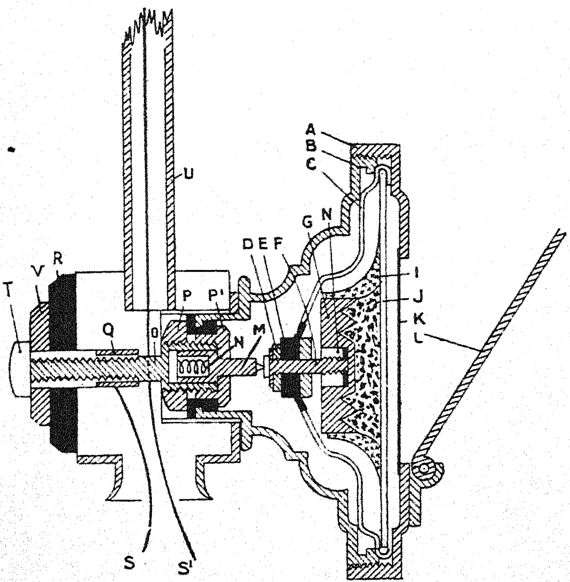
Some of these microphones have carbon shot instead of granulated carbon. This type has recently been introduced into the service.

There is a similar form of Ericsson transmitter to this to be met with, but it differs in having an iron disc instead of carbon, and the inner face of the disc is fitted with a small metal dish, which has a number of indentations that project into the carbon granules when in position, making a good contact and preventing "packing."

Capsule Microphone.—The latest microphone to be met with is the capsule type. It is shown in Fig. 43. The advantage of this type is, that if it becomes defective, it is only necessary to replace the inner portion G, or capsule, by another.

These microphones are not only fitted to the hand-telephone sets, but are also fitted into detached microphone cases. The type shown consists of a metal case A, B, in two parts, the front portion A screwing into B, as shown. Inside the case is the capsule C, which has fixed at one end a metal contact, D, insulated from the case by insulation E. The metal contact has screwed into it a screw, F, the other end of which passes into a slot in the carbon block G, and screwing on to this end is a brass nut, H, which holds the carbon block in position. Granulated carbon is kept in position in front of the carbon block by a wrapping of flannel, I, and the carbon disc J; the latter being secured by the metal case of capsule being spun over it, as shown.

Wire gauze, K, is placed in the front of this, to prevent damage to the carbon disc, also a hinged cover, L, which should be opened when in use. Contact is made with the capsule by the contact point M, which is pressed forward



AB Metal case	*I* Flannel	*PP'* Nuts
C Capsule case	*J* Carbon disc	*Q* Metal ring
D Metal contact	*K* Wire gauze	*R* Insulating washer
E Insulation	*L* Cover	*SS'* Microphone wires
F Screw	*M* Contact point	*T* Sleeve nut
G Carbon block	*N* Spiral spring	*U* Metal frame
H Brass nut	*O* Threaded bolt	*V* Metal washer

FIG. 43.

by the spiral spring N, that fits into a recess in the end of a threaded bolt, O. The contact point M is held in position by the two nuts P, P'. Q is a metal ring to which one of the

primary wires, S, is connected, the other wire, S′, going to the pivot of pressel switch.

Circuit.—The current from the primary circuit will, let us say, enter by S, and pass through Q, O, M, D, F, G, through the granulated carbon to J, then to the metal casing which extends up to the pressel switch; the latter being pressed, the current will pass up the switch to the pivot, where the wire S′ is connected, and back through the remaining part of the circuit.

The two wires that go to the receiver are not shown in figure.

Some of these microphones have a thin disc of mica placed in front of the carbon disc to protect it.

Receivers

There are many types of receivers to be met with, and their principle of construction is a modification of the Bell receiver, previously described.

Ader.—In this receiver A is a horseshoe permanent magnet, to the north and south poles of which are screwed L-shaped soft iron pole pieces B; these become magnetised, and extend the poles to the top of the vertical limb; over each limb is slipped a bobbin of fine wire. The coils C are joined in series, and the ends brought to two terminals, usually found on the outside of the receiver. Opposite the pole pieces a tinned iron disc, D, is placed and is kept from touching the pole pieces by a brass distance ring, E; another brass distance ring, E′, is placed on top of the disc. The earpiece F is of ebonite, and into this is fitted a soft iron ring, G, its use being to concentrate the line of force given out by the magnet poles to the centre of the disc, making the receiver more sensitive. It is a special feature

in the Ader receiver. This type of receiver is not used very much in England now (Fig. 44).

Ring Magnet Receiver.—This type of receiver is very extensively used at the present day, and is nearly always found in the Hand Micro-telephone shown on p. 58. Fig. 45 shows this receiver, which consists of a compound flat steel ring magnet, magnetised across one of its diameters, NS. The L-shaped iron pole pieces are screwed to the magnetised ring at these points, thus extending the polarity to the top of the vertical limbs. Bobbins of wire are slipped over these, as in the Ader type, and there is also an iron disc with a paper distance ring on each side of it. The uppermost ring is sometimes

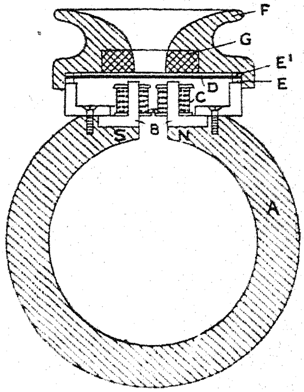


FIG. 44.

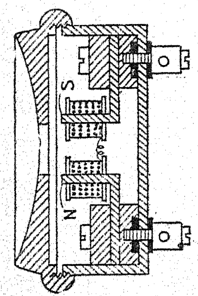


FIG 45.

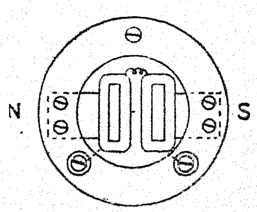


FIG. 45A.

dispensed with, by having a ring formed in the ebonite

earpiece. It is enclosed in a metal case. The resistance of the receiver coils is usually about 120 ohms. This type of receiver is found in nearly all receivers of Hand Micro-telephones.

Gower Receiver.—This is an old form of receiver, and is still extensively used. It differs chiefly in the shape of the magnet, which is semicircular, as in Fig. 46. A type resembling this, is used in the service in the Telephone Sets Portable D. Mk. II.

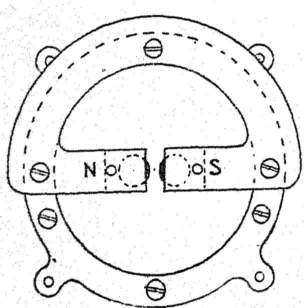


FIG. 46.

Head Receivers.—These are ordinary ring magnet receivers, fitted into aluminium cases for lightness, with a spring, or a web band fitted to them to fit over the head. They are used to allow the operator to have both hands free, the microphone in this case usually being fixed either to the body or a bracket.

Loud-speaking Receivers.—These consist of a large double-pole receiver, which has fixed to it a magnifying trumpet; their use being for communication between offices in the same building, so that messages can be given without using a call bell.

Before concluding this chapter I should like to add a few words about the theory of the receiver for the benefit of those who are desirous of becoming more conversant.

It has been proved by experiment that there is a relation between the strength of the magnet in the receiver and the size of the iron disc.

The relationship is as follows :—

(*a*) For a receiver with a given magnetic field there is a thickness of disc which gives a maximum effect.

(*b*) If the thickness of disc is known for a certain magnetic field, there is a certain diameter for the disc which gives the best result. The stronger the field the greater the diameter.

(*c*) The best result is also obtained when the magnet and coils are arranged so that the greatest number of lines of force pass through the coil in a direction at right angles to the plane of the coil, and in which these vary most with any movement of the disc.

Some receivers are fitted with an adjusting screw at the back, which will allow the magnet to be pushed nearer the disc should the sounds be indistinct.

The writer is invariably asked by students, why it is necessary to polarise the cores of receiver coils, or, in simple words, why is a permanent magnet required? It is explained theoretically as follows :—

The pull between the poles of the receiver and the iron disc varies as the square of the intensity of the magnetic force in the space between them. It will be seen, therefore, to get the greatest vibration in the disc, the intensity of the pull must vary as much as possible. Let H represent the strength of the field due to permanent magnet, and h that due to one of the speaking waves, then the pull on the disc will vary between $(H + h)^2$, when the current enters the magnet coil in such a direction as to further strengthen the field, and $(H - h)^2$ when the current enters by the opposite end of coil, which weakens the field.

The difference between these two, amounts to $4Hh$, which will represent the difference in pull on the disc.

If the permanent magnet was not there, the pull on

F

disc would vary between o and h^2, and as h is a very small quantity (being due to the weak current passing round the receiver coil) its square would also be very small; in fact, very much less than $4Hh$, in which the large value H is included.

From this it will be seen that the intensity of action of a receiver is proportional to the strength of the permanent magnet within certain limits; therefore, it is important to see that the permanent magnet is kept up to strength.

It must be understood that the vibrations set up by the receiver disc are caused by the variations in the strength of the magnetic field. As the polarised pole pieces in the receiver exhibit a north and south polarity, due to the permanent magnet, this polarity will be increased in strength when the current passes through the coils in such a direction as to give it a similar polarity, and will be decreased in strength when the current enters by the other end of coil, which will try to reverse the polarity due to the permanent magnet.

Lightning Protectors

To prevent damage being done to the bell, armature of magneto generator, receiver and induction coil of a telephone, it is necessary to fit a telephone with a lightning protector or discharger, as all the above are wound with fine wire to a high resistance, and such coils are especially liable to damage by lightning. A lightning charge will, when the conditions of the circuit are favourable, spark across a comparatively great thickness of insulation, rather than pass through a large number of turns of wire. Most telephones are fitted with some form of discharger in which

a short spark gap, usually air, is arranged. If this is not done, and a line wire is struck by lightning, the charge is liable to spark across the insulation of the wire on the coils, and fuze the wire itself.

A common form of protector is shown in Fig. 47, and consists of two metal plates with saw teeth, connected to the two line terminals; fixed close to, but not touching, is a third metal plate, which has fitted to it a terminal for connecting an earth wire to. The distance apart of toothed and earth plates should not exceed the thickness of an ordinary receiver diaphragm (10 mils.), a piece of which can be kept and used as a gauge.

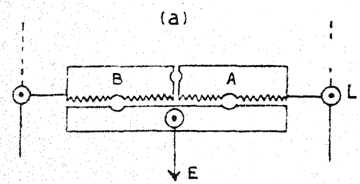


FIG. 47.

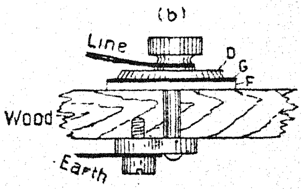


FIG. 47A.

If the lightning should strike the line wire L, instead of entering the telephone it will pass to the strip A, jump the air gap, and earth itself through the earth connection E.

Another form of protector that is largely used with indoor or stationary telephones, is shown in Fig. 47A, and consists of two circular metal plates, D, F, separated by a disc of mica, G, which is perforated with several small holes to provide an air gap. Each plate has a terminal fitted to it, D being connected to the line wire, and F to earth. Two of these would be required for a telephone, and are usually permanently fixed to them, as shown in Fig. 47A.

Summary

Carbon pencil microphones are not used to a great extent nowadays.

The primary or microphone circuit is local, and in a portable telephone never has more than two cells. If more than two are used, the carbon in microphone gets heated, and the working of the telephone is not so good.

If the receiver or hand-telephone rests on a switch hook or cradle, always replace it when conversation is finished.

When using a hand-telephone with pressel switch, if you are waiting for an answer, always release the switch; this saves the battery.

Don't forget to close pressel switch when talking, as this closes your microphone circuit; otherwise you will not be heard at the other end.

Solid back transmitters are mostly used with stationary telephones.

Granulated carbon transmitters are more sensitive than the pencil type.

Packing is a term given to granular carbon transmitters, when the granules are found to cling together. Tapping the case of microphone will often put this right.

Never open a granular carbon transmitter unless it is absolutely necessary. When doing so, open it carefully, and always have a sheet of paper underneath to catch the carbon.

It would be advisable to have a sectional diagram when replacing the parts, to avoid making a mistake. A metal or an insulating washer put in the wrong place will upset the working of it.

An ebonite washer is usually found at the pivot of a pressel switch; when replacing it, be careful not to put it between the metal of switch and the wire.

A granular microphone will work without an ebonite

mouthpiece, but it is better to have one, as it will practically shield it from other sounds.

If the case of a granular microphone is held together by screws, they should be kept tight; if loose, they will allow the granulated carbon to escape.

Cases containing capsule microphones are usually threaded and in two parts, which screw together.

The Bell receiver is still used with some telephones.

Ader receivers are not often met with now.

Always see that earpiece of a receiver is screwed home.

Some receivers have only one ring, the other being formed in the ebonite earpiece.

If the ring is removed from under the disc in the receiver the sounds will not be heard so distinctly.

If the disc is removed the sounds will not be heard at all, although the circuit will not be broken.

A receiver is always connected in the secondary circuit, and a microphone in the primary.

Always remember that the primary circuit is local, and consists of a two-cell battery, microphone, and primary of induction coil in series, and the secondary circuit consists of your own secondary of induction coil and receiver, joined in series with the receiver and secondary at the distant station, by means of the lines wire. Some telephones have the magneto bell also in this circuit. As explained later, this does not affect the working of the secondary circuit.

Receiver discs are always made of iron, sometimes they are coated with black enamel instead of being tinned; this is only to prevent rusting.

The ring magnet receiver is mostly to be met with in modern telephones. It is nearly always used in the Hand Micro-telephone. The magnet is usually compounded, that is, made up of a number of rings screwed together (for reason see p. 22).

An indiarubber ear-cushion is often fitted over a receiver to enable the sounds to be heard more distinctly. Being soft, it allows the ear to be buried in it and thus prevents external sounds from reaching it.

The hand micro-telephone is known in the service as Telephones Hand. There are various types of these, some of which will be explained later.

In a microphone, the space between carbon block and carbon disc should never be entirely filled with granulated carbon, or it will encourage "packing," and make it less sensitive.

Granulated carbon is sold for microphones.

The lead of a blacklead pencil, ground up, is a good temporary substitute for carbon.

Of the four wires that are connected to a hand-telephone, two go to the receiver, and the other two to the microphone. They are usually bound at their ends with different-coloured cotton.

To identify the wires in a hand-telephone, the two that give sounds in the receiver when touched between the poles of a cell, will be the receiver wires.

Ebonite is now made for receiver cases with canvas embedded in it, to render it practically unbreakable.

The following list of prices of telephone accessories may be of interest to some:—

Ring magnet receiver, 7*s.* 6*d.*

Granulated carbon microphone, 7*s.*

Hand micro-telephone, 21*s.* 6*d.*

As supplied by J. McMillan & Co., Glasgow.

Microphone capsule, 2*s.* 3*d.* each.

Telephone induction coils for long-distance work, 2*s.* 3*d.* each.

As supplied by The International Electric Company, Redcross Street, London.

CHAPTER VI

PORTABLE AND FIELD TELEPHONE SETS

HAVING in the early part of Chapter V. dealt with the speaking circuits of a telephone with induction coil, it will only be necessary to add to this a magneto generator and polarised bell, and thus form a complete telephone set. Fig. 48 represents the circuits of a telephone thus arranged.

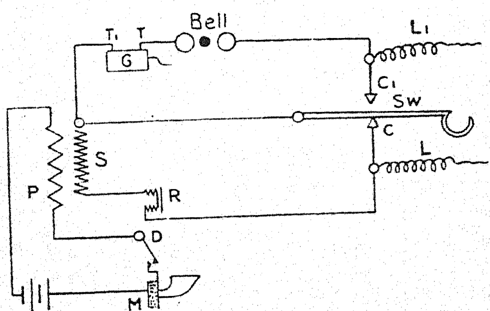


FIG. 48.

In tracing the circuits of a telephone, one must always bear in mind, if the hand-telephone or a receiver hangs on a switch hook, the call circuits will be traced with the switch hook in the Down position, and the secondary circuit with it in the Up position.

The circuits in Fig. 48 are as follows :—

Outgoing Call.—Turn handle of generator, and current will leave by T, through home bell B, out by L_1 to distant telephone, back by L to C, along metal of switch to T_1.

Incoming Call.—In by, say, L_1, through bell and generator, switch hook to C, and back by L.

Primary Circuit.—Close pressel switch D. From positive of battery through microphone carbons M to D, P, and back to negative of battery.

Secondary Circuit (Induced current).—From, say, bottom end of secondary coil S to receiver R, out by L to far station, back by L_1 to C_1 (the switch hook being Up) to top end of coil S.

Portable C. Telephone

Fig. 49 represents a telephone that is largely used in the service, and is known as "Telephone Sets Portable C."

It consists of a box containing two dry cells, a magneto generator, polarised bell, induction coil, testing plug, and a "Hand Telephone C." The cells are joined in series (as shown in Fig. 49A), and fit one in each corner at the back of the box. The Hand Telephone C. fits on a rest when not in use. It differs from the one shown on p. 58 by the pressel switch having an up and down contact, that is, it makes a contact in the released as well as the pressed position, thus doing away with a special switch for the bell or call circuit, as this circuit passes through the switch when it is in the up or released position as explained, in circuit diagram, Fig. 49A.

The generator handle and testing plug are carried, when not in use, by holders in the lid. The telephone is also

provided with three terminals, two for the line wires and one for an earth connection. Between the line terminals is fitted a common form of lightning discharger (explained on p. 67).

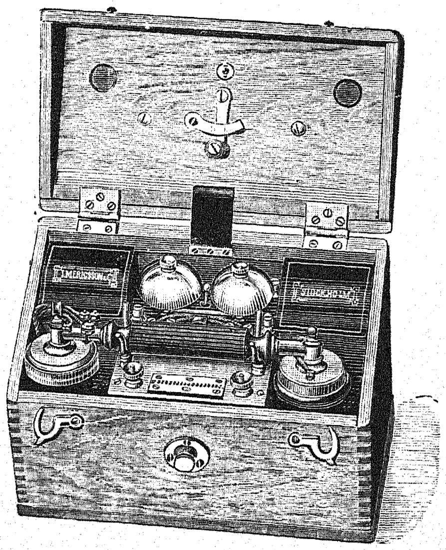


FIG. 49.

There are usually four distinct circuits in a telephone—

(1) Outgoing call,
(2) Incoming call or reply,
(3) Primary circuit } Speaking circuits.
(4) Secondary circuit }

It will be readily understood that the object of the generator, is to send the current to the distant telephone to ring its bell, therefore, when the home bell is being rung, it is not necessary for the incoming current to pass around

the armature coils of generator. To prevent this, a cut out is used, which short circuits the armature. It consists of a piece of clock spring, I, connected at one end to the metal

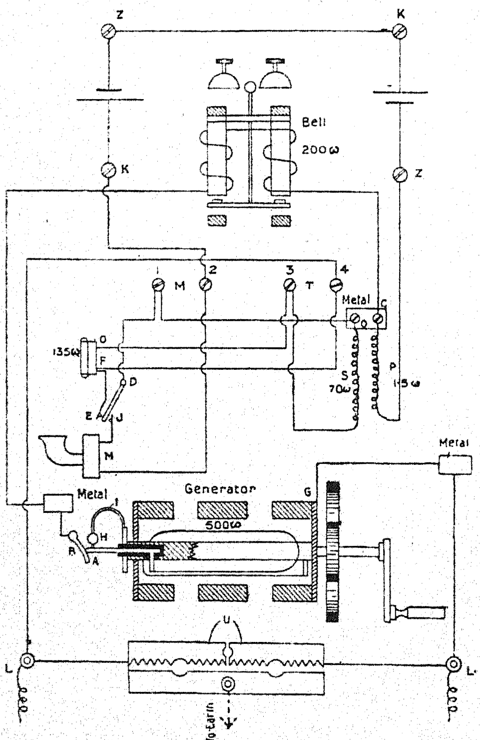


FIG. 49A.

of armature, and having fixed to it at the other end a metal weight, H, which, when at rest, touches a stud connected to the pin A. When a current entering the armature from the brush B gets to A, instead of going through the coils, it

goes to the metal weight H, to the clock spring I, and from it to the metal of generator, leaving this at G, and back by the other line wire.

When the armature is rotated, the short-circuit device is broken, as the rotary motion of the armature causes the clock spring to fly out, and the weight H to leave the stud.

The circuits can be traced on the diagram as follows:—

(1) **Outgoing Call.**—From A to B, bell coils, C, Q, 1, D, E, F, 4, L, to the distant telephone bell, and back to L_1, to other end of generator G. (The home bell should also ring in this case.)

(2) **Incoming Call.**—In by, say, L to 4, F, E, D, 1, Q, C, bell coils, B, A, H, I; through metal of generator to G, L_1, and back by the other line wire or earth return.

(3) **Primary Circuit.**—From positive of battery to K, through microphone to J. The pressel switch being pressed, to D, 1, Q, C, primary coil P, Z to negative.

(4) **Secondary Circuit.**—The induced current caused by talking into the microphone will leave the secondary coil, say at Q, to C, bell coils, B, A, H, I, G, L_1 to distant telephone receiver, back by L, 4, F, through receiver coil to O, 3, back to secondary coil.

Also trace circuits on key diagram.

The centre terminal is used for connecting an earth wire to.

When the telephone is used with a line and return wire, during stormy weather, if the wires be overhead ones, it would be advisable to connect a wire from the centre terminal to the earth. This will prevent damage being done to the instrument if they are struck by lightning, as the discharge would jump the air gap at discharger U, and earth itself.

If the earth terminal is used as a return, and the line wire is connected to L, the plug should be in right-hand hole.

For field work, using a wire laid on the ground and an earth return, it is usual to connect the line and earth wires directly to terminals L, L_1.

Rough Tests.—The rough tests for this instrument are as follows:—

(*a*) To test the Bell Circuit.—Turn handle of generator with line wires disconnected; bell should not ring. Insert plug between the two small brass strips U (or connect line terminals) and repeat; the bell should now ring loudly.

(*b*) To test Speaking Circuits.—Place receiver of telephone to ear, close pressel switch D, insert plug between brass strips U. On blowing into microphone, or making and breaking pressel switch, sounds should be heard in receiver.

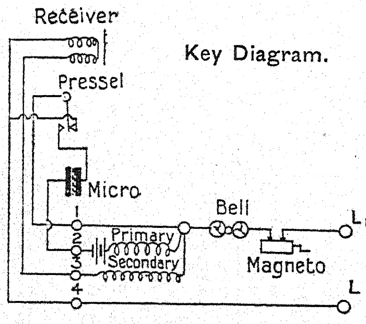


Fig. 50.

Tests in Detail.—If the bell fails to ring, it may be due to the pressel switch not making contact in the released position at the point E; look to this. If it still fails, it may be due to a mechanical fault at the generator, such as the rubbing contact at B not touching the armature, or the bell armature may be out of adjustment. To put either of these mechanical faults right, it will be necessary to open

the centre partition of the instrument, by disconnecting the battery wires at Z and K, and then removing the holding-down screws. As the top is a neat fit, it will require careful handling.

If sounds are not heard in receiver when applying test (*b*), it will prove a fault in either the primary or secondary circuit, or perhaps both.

To test the primary circuit for continuity, connect a current detector (low resistance coil) in series with it at any convenient point, say at battery; close pressel switch, when a deflection should be obtained in detector. If not, look carefully to the battery connections by removing the metal covers from the cell boxes, and then test each cell by connecting the detector (low resistance coil) between the positive and negative of each, when a hard-over deflection should be obtained; if not, the battery should be replaced by a new one. If the fault has not been detected, tap the microphone gently, as the carbons may have packed a little. If still undetected, trace out circuit carefully with a battery and detector in series, as explained on p. 93.

To test secondary circuit, join a two-cell battery and detector (high resistance coil) in series with the line terminals, L, L_1; plug should *not* be inserted. When the pressel switch is pressed a deflection should be obtained in detector. A deflection is also obtained when this switch is released; the current in this case flows round the bell circuit. It is the deflection when the switch is pressed that is wanted. If this is not obtained, short circuit the terminals 3 and 4 by a piece of wire or metal of any kind; if a deflection is now obtained, it proves the fault is in receiver or leads. Repeat by short circuiting on terminals at back of receiver; if no deflection, it proves a break in receiver leads. If there is a deflection, it proves a break inside receiver. If a fault is still on, open the middle partition,

and trace out circuit carefully, as explained on p. 93, with the aid of a circuit diagram.

The Ericsson Field Telephone, or, as it is known in the service, "Telephone Sets Portable D. Mk. I."

This is an extremely useful telephone for field work, and consists of a red vulcanite case, containing an induction coil, vibrator magnet, a two-cell dry battery, two small condensers,

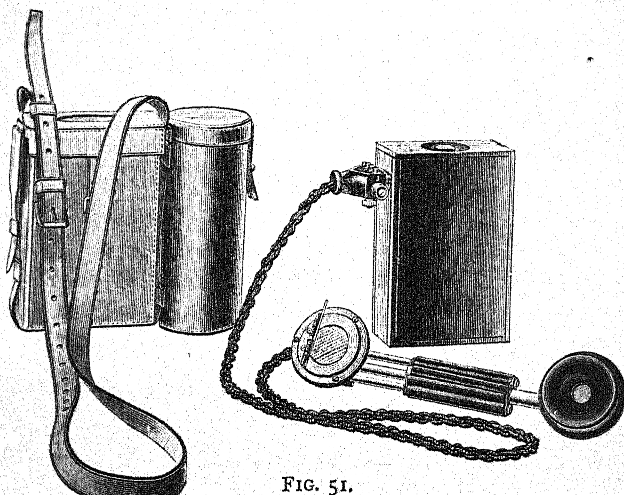


FIG. 51.

and a double spring push. Fig. 51 represents the instrument removed from its leather case and fitted with a telescopic hand micro-receiver (known as "Telephone Hand D" in the service) with four-way connecting cord, which terminates at one end with an ebonite plug fitted with three terminals. This plug fits into a recess in the side of the case as shown. A buzzer call is used instead of a generator and bell, as this has the advantage of overcoming a greater line resistance, and will, in fact, work through a broken line wire in contact

with the earth throughout. It can also be used as a telegraph instrument to send the message by the Morse code if speech is not clear. There are three line terminals, which are marked DL, CL, and E. For ordinary work, with a line wire and earth return, the line should be connected to DL, and the earth connection to E.

The Buzzer.—Before tracing the circuits of this telephone, it will be advisable to understand the action and use of the buzzer.

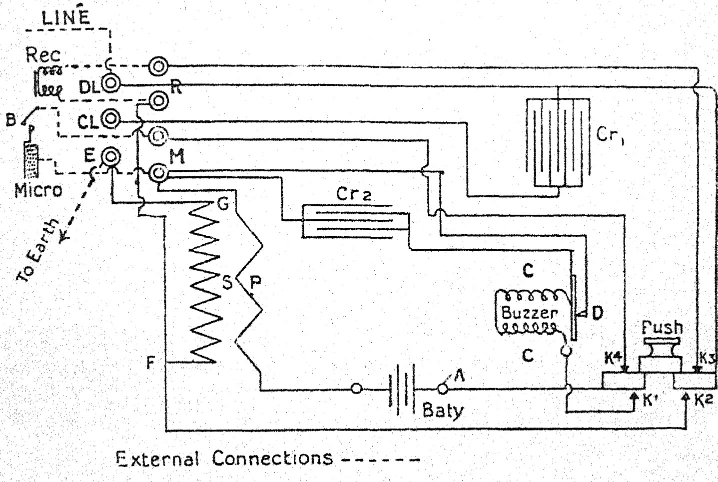


FIG. 52.

The attention of the distant station is called by hearing a buzzing sound in their receiver. This is due to the push of the home instrument being pressed, causing a current to pass round the buzzer coils C, C, as will be seen on tracing the call circuit, Fig. 52.

The action of the buzzer is similar to that of an electric trembling bell, only that the armature, being very thin, will

therefore give a buzzing sound when it vibrates. In the Ericsson and Portable D. telephones, the buzzer coil is in series with the primary of the induction coil, so that the armature vibrating will momentarily break the circuit, causing the iron core inside primary coil to be magnetised and demagnetised, inducing a current in the secondary coil, which reproduces in the far receiver the buzzing noise.

A small condenser, Cr_2, is joined between the adjusting

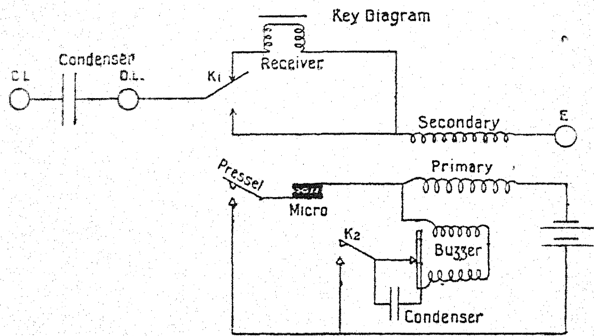


FIG. 53.

screw and the armature, chiefly to prevent sparking between these two contacts.

The seven terminals shown in Fig. 52 are connected to seven metallic connections on the seven-point ebonite plug, which is connected to the hand-telephone cord. When this is in position, the two terminals R are connected to the receiver, and the two marked M to the microphone, the other three being in contact with three terminals on the ebonite plug, and are used for connecting the line and earth wires to.

The circuits are as follows:—

Line Connections.—Earth wire to E, and line wire to DL.

Outgoing Call.—Press push, and current will flow from positive of battery to K_1, C, C, D, M, P, to negative. This will induce a current in S, starting from F to K_2, DL, out by line to distant telephone receiver, and back by earth to E, G.

Incoming Call.—In by DL, to K_3, R, receiver coils, F, S, G, E, and back by earth.

Primary Circuit.—Close pressel switch B from positive of battery to K_4, M, B, through carbons to P, and back to negative.

Secondary Circuit.—Induced current (caused by talking to microphone) starting from F, to R, through receiver coils to K_3, DL, out by line, and returning by earth to E, to G.

It will be seen that the outgoing call buzz does not pass through the home receiver, as the push, when pressed, breaks the circuit to it at K_3.

Also trace circuits on key diagram.

Rough Tests

(*a*) To TEST OUTGOING CALL CIRCUIT.—Press push, and place the ear near the side of telephone case, when the buzzer should be heard.

(*b*) To TEST SPEAKING CIRCUITS.—Connect the line and earth terminals (short-circuit line terminals) by a piece of wire. Close pressel switch. On blowing into microphone, or making and breaking pressel switch, sounds should be heard in receiver.

Tests in Detail

(*c*) If the rough test (*a*) fails, remove cover of instrument, and press Key 1. If the buzzer magnet still fails, look to the adjusting screw D, and see that it is just touching the armature. If you think it requires adjusting, remove small screw-driver from inside of lid, and adjust it by slowly

turning the adjusting screw in the required direction, keeping Key 1 pressed all the time with the other hand.

This requires a very fine adjustment, also patience. If still at fault, test battery by putting it on to the Q coil of a detector, which should indicate a hard-over deflection if correct. If still undetected, trace out circuit carefully and look for a loose or broken connection.

When discovered, test by joining terminals DL and E by a short piece of wire; on pressing Key 1 a loud buzz should be heard in your receiver.

(*d*) If test (*b*) fails, test primary circuit by connecting the Q coil of detector in series with this circuit, say at A; on closing pressel switch B a deflection should be obtained in detector; if not, trace out circuit carefully and locate.

(*e*) If test (*b*) still fails, join two cells and I coil of detector in series with terminals DL and E (connect up to DL, and only make and break the circuit by touching the wire on E), when a deflection should be obtained. If not, remove the wires that you have connected to DL and E and touch them on the terminals R on plug. This should give a deflection, as it sends a current up the receiver cord to receiver and back. If not, touch on terminals at the back of receiver; if this is faulty it will prove a break inside receiver. Open and put right. If it is not faulty, trace out the rest of circuit carefully with detector and battery.

Tapping a Telegraph Wire

As a condenser will not work with a direct current, and as telegraph instruments are worked by a direct,

or battery, current, if we place in series with a line terminal of our telephone a condenser, it will be possible to utilise a telegraph wire for sending messages by telephone. The direct current passing along the wire to the far telegraph instrument, will not enter the telephones, on account of the condensers acting as a break to such a current; but the two instruments will be able to carry out conversation, as a telephone is operated by an alternating current, which will in no way affect the telegraph instruments, or indicate in any way that their wire is being used.

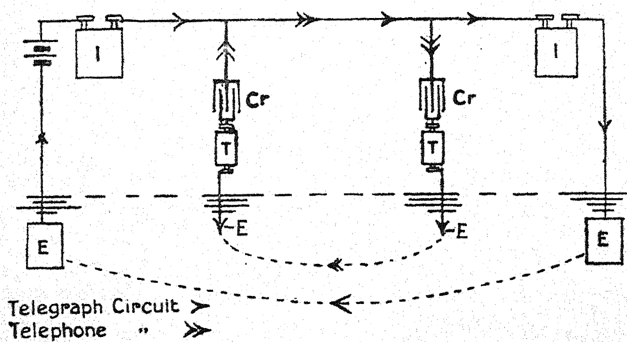


FIG. 54.

Fig. 54 represents a scheme of the above arrangement. T are the telephones, C the condensers (shown outside the instruments for clearness), and I the telegraph instruments, connected by a line wire and earth return.

To use the instrument at present being described in this way, connect the line wire to terminal CL, and earth connections to terminal E. On tracing the incoming or outgoing buzzer, and speaking currents, it will be seen (Fig. 52) that instead of their leaving or entering by DL,

it will be by CL, and in doing so must pass into the condenser in each case, and as these are alternating currents, they will pass through and round the rest of the circuit as before.

Telephone Sets Portable D. Mk. II.

This telephone is carried in a leather case, and consists of a red vulcanite case having a terminal at each end, one being for the line wire, and the other for the earth connection. It contains an induction coil, two-cell dry battery, a vibrator call magnet, two condensers, and a push for working the call circuit. The receiver and microphone are entirely separate, the former being carried in a leather case, and has a strap of webbing that fits over the top of the head, which is secured by a buckle, for holding the receiver securely to the ear when in use. The microphone is contained in a small aluminium case, which has a push button, and is of the capsule type.

The small condenser Cr_2, Fig. 55, is connected between the adjusting screw and the iron of vibrator magnet, to prevent sparking between this screw and armature, when the latter vibrates. The condenser Cr_1 is connected in series with the line terminal L, and is always in circuit, the object being to enable a telegraph wire to be tapped (see p. 82), and do away with a special connection for this purpose. The talking and buzzer currents, being alternating, will pass through the condenser. The action of the buzzer is similar to that explained on p. 80. The Push 1 is found in the cover, and can be worked when it is in the leather case, as a piece of soft leather is fixed in the top of the case, which enables it to be pressed.

The receiver and microphone fit into separate leather pockets on the outside of the case.

The circuits are as follows :—

Outgoing Call.—Press Push 1 and the current will

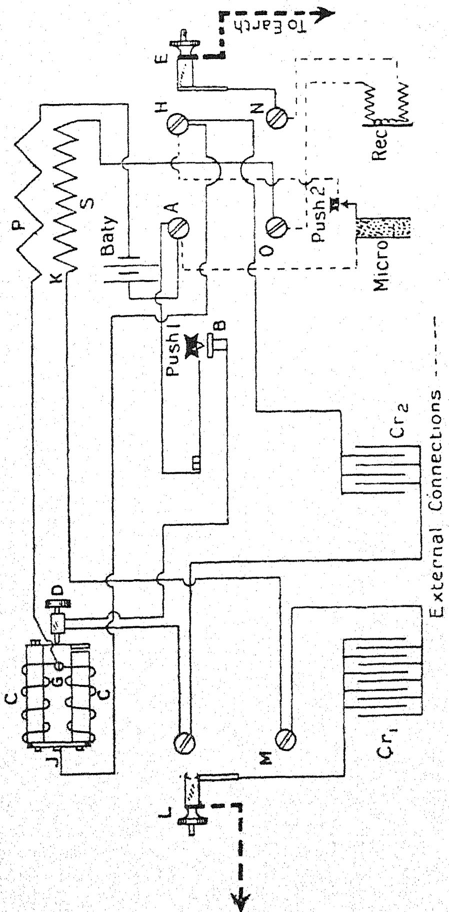


FIG 55

flow from positive of battery to A. Push 1, B, D, J,

enter both bobbins (in parallel) from metal of vibrator, uniting at G, through P, back to negative of battery. The armature vibrating will give a buzzing sound, and an induced current will be set up in the windings S of the secondary coil, due to the make and break of the circuit at the adjusting screw, as this current will pass through the primary P of the induction coil, and carry with it the buzz. The current induced in the secondary coil S will leave by, let us say, K, and flow to M, through Cr_1 to L, out to the far telephone receiver, and return by earth to E, N, receiver, O, and

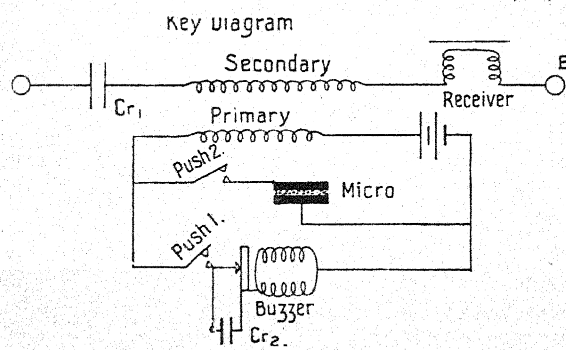


FIG. 56.

back to the secondary coil S. The home receiver will also buzz.

Incoming Call.—In by line L, Cr_1, M, K, S, O, receiver coil, N, E, and return by earth. A buzz should be heard in receiver.

Speaking Circuits.—PRIMARY.—Press Push 2, and a current will leave positive of battery and flow to A. MICROPHONE.—Push 2, H, J, through vibrator coils to G, P, to negative of battery.

Secondary Circuit.—An induced current will be set

up in S, owing to a variable current passing through P, due to the microphone being spoken into. This induced current will flow from, say, K to M, C*r*, L, line to the far telephone receiver, return by earth to E, N, receiver, O, back to the secondary coil S.

Rough Tests

(*a*) CALL CIRCUIT.—Raise the instrument in case to the ear; press Push 1, and the buzzer should be heard. Join line terminals L and E by a piece of wire. On pressing Push 1, a loud buzzing should be heard in receiver.

(*b*) SPEAKING CIRCUITS.—Press Push 2. On making and breaking Push 2, it should be heard in receiver.

Apply also to Key diagram (Fig. 56).

Tests in Detail.—If test (*a*) fails, remove cover of instrument and carefully inspect the adjusting screw of vibrator, to see that it is touching the armature. (This is the only mechanical fault likely to occur in this circuit.) It may require a little adjusting. If still out of order, test circuit for continuity by connecting a detector (low resistance coil) in series with this circuit at the battery. Press Push 1, when a deflection in detector should be seen; if not, test each cell separately by connecting them up to the detector (Q coil), when a hard-over deflection should be obtained, if in good condition. If the battery is not faulty, then there is a break in the circuit, which should be discovered by tracing. When discovered and put right, repeat (*a*).

(*c*) If it still fails, join two cells in series with the L and E terminals, place the receiver to ear. On making and breaking the circuit, at say terminal L, a click should be heard in the receiver. (This is also testing the secondary circuit.) If not, touch the two wires from the two cells that you are using on to the terminals N and O, when the make and break

should be heard in receiver, as this tests receiver and cord; if not touch on receiver terminals. If now heard, it proves the receiver cord to be broken, if not, a disconnection inside receiver.

If the fault is not in receiver or cord, join a detector (I coil) in series with the two-cell battery that you are using and connect it to E and M, when a deflection should be obtained. If still at fault, trace out the remaining part of this circuit, with the aid of diagram, and locate thus—

(*d*) If test (*b*) fails, test the primary circuit by connecting a detector (Q coil) in series with this circuit at the battery, or any other convenient point; press Push 2, when a deflection should be obtained in detector. If not, see that the front of microphone case is screwed up tightly, and hold it in a vertical position while pressing push. Slightly tap microphone and repeat. If still at fault, trace out the circuit carefully and look for a break.

(*e*) Secondary Circuit.—If test (*c*) has been applied and answers, this circuit must be correct, as it is common to both the outgoing part of call circuit and secondary. If it has not, and the fault is still on, apply it.

Concerning Portable C. Telephones

When calling up on the Portable C. telephone, always turn the handle rapidly; if not, the armature may fail to give out its current.

The quicker you turn the handle of a magneto generator, the higher the voltage generated.

To identify the wires of a Handle Telephone C., when disconnected from the box, touch the wires between the

poles of a single cell, until you find two that will give you clicks in the receiver with the pressel switch either pressed or released. They will be Nos. 3 and 4 (mark them at random). One of the discovered wires and one of the undiscovered wires should give sounds in the receiver with the pressel switch Released only. The previously discovered wire will be No. 3, and the other No. 1.

When using a Portable C. telephone with an earth return, if the line wire is connected to the left terminal and earth to middle terminal, the plug should be in right-hand hole of lightning protector.

If the line wire is connected to the right terminal and earth as before, the plug should be in left-hand hole. If two line wires are used, connect one to left and one to right line terminal (plug should not be inserted); also connect an earth wire to middle terminal, if working with overhead wires in the field in stormy weather.

The metal gongs of bell can be removed for cleaning by unscrewing the nuts on top. When replacing, be careful to tighten the nuts well.

When replacing or inserting a new battery into the Portable C. telephone, be careful to connect the centre terminal or positive pole of the cell to the terminal in box marked K, otherwise you may have your cells opposing each other.

If the centre partition is removed at any time, two bell-mouthed tubes will be seen coming up from generator bearings. These are lubricators.

The magnet pole pieces of some generators are copper coloured. They are iron, and are copper plated to prevent rusting. When removing any part of the telephone, be careful to note the procedure of taking to pieces, as this will facilitate the replacing of same.

The two cells in the telephone can be used for carrying out the "Tests in Detail" by disconnecting the wires from

the cells that go to the Z and K terminals nearest the front of box, and connecting them to the circuit under test.

Concerning Portable D. Telephones

To adjust the buzzer armature, press the buzzer key, and with the aid of a small screwdriver very carefully and slowly turn the adjusting screw until the armature gives off a buzz. When doing this, be careful to watch the armature to see that it is not bending, as if the screw is turned too much it will cause this, and upset the working of it. The screw should only just touch the armature. When properly adjusted it should give off a highly pitched note.

The adjusting of buzzer armature is a very careful operation, and when once adjusted should not be interfered with.

If the battery is nearly exhausted it will fail to work the buzzer. A two-cell battery should indicate not less than two volts on a voltmeter to work a buzzer properly.

The battery in the D. Mk. I. telephone consists of two cells joined in series inside the one casing, and therefore represents 3 volts.

The battery in the D. Mk. II. telephone consists of two separate cells joined in series.

Never allow the positive and negative wires of a cell or battery to touch each other. This considerably shortens the life of them.

Never remove the condensers unless it is absolutely necessary, as the wire connections are very apt to break off short at the point where they are connected to the tinfoil, rendering it very difficult to repair.

When removing screws, it is advisable to always place them on a sheet of paper, to prevent losing them.

Summary

The microphone is that part of a telephone that is spoken into.

Never use more than two cells for working the microphone circuit, otherwise you will heat the carbons, making them less sensitive.

Dry cells are always used with portable telephones, and should last at least twelve months.

A dry cell is of little use for telephone work when it indicates less than one volt.

Always keep the terminals of a telephone clean and dry.

Never press your finger or anything against the disc of a microphone; being carbon, and very thin, it will easily break.

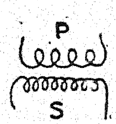
When testing a circuit never touch the wire on the top of the terminal, as it is coated with lacquer, which is an insulator. Always touch the wire on the threaded bolt, or on the underneath part of terminal, where it grips the wire, as this part is not lacquered.

When using a screwdriver to remove small screws, be careful not to let it slip, as, the screw being brass, the head is easily cut off. Always press fairly hard on the screwdriver when turning it, especially when starting a screw.

A telephone induction coil is usually indicated thus—

Primary

Secondary



The iron core is not shown.

The ends of the primary of an induction coil can be identified by being a little thicker than the ends of secondary. They should also come away near the middle of the coil, as the primary is the inside winding; they are usually a different colour to the secondary.

A practical way of identifying them is to join first one pair of ends, and then the other, in series with the Q coil of a detector and a single cell. The two that give the greatest deflection will be the primary.

The primary coil is always of a much lower resistance than the secondary. A common form of telephone induction coil has a primary resistance of about $1 \cdot 5\ \omega$, and a secondary of about $25\ \omega$.

When receiving a message on a telephone, speech will be made clearer if you release your own pressel switch, as this does away with side tone in your own transmitter, caused by extraneous sounds reaching it. Don't forget to press it when you reply.

When using a Hand Micro-telephone, always hold it in a vertical position. If it is held on its back, you tend to break the circuit through it, by allowing the granulated carbon to fall back from the carbon disc.

A telephone receiver is a good substitute for a detector when testing a circuit. It should be joined in series as the detector would be, and a click should be heard in receiver every time the circuit is made and broken, if the circuit is correct.

A microphone can be made more sensitive sometimes by slightly tapping its case, as the granulated carbon sometimes packs or clings together. Carbon shot microphones are not as liable to packing, and are coming to the front a lot just now.

A carbon shot microphone only differs from a granulated carbon one, by having the granulated carbon replaced by carbon shot.

If a capsule microphone has its carbon plate broken, it cannot be replaced, as the metal case that holds it in position is spun over it. The capsule can be removed by unscrewing the front of the case. A disc of mica and wire

gauze is sometimes placed in front of the carbon disc to protect it from injury.

When connecting a wire to a terminal, always connect it with a right-hand hook, thus 

If a left-hand hook is used, there is a tendency to force the wire out, when screwing up the terminal.

To locate a fault in a circuit by means of a battery and detector in series, the test should be carried out as shown.

Connect positive to one end of circuit A, as shown. When a contact is made at B a deflection will be obtained in detector, also at C. When D is touched there will be no deflection, proving the break to be between points C and D. The wire may be broken, and not the insulation; this can be detected by bending the suspected part in the hand, when it will at once present itself.

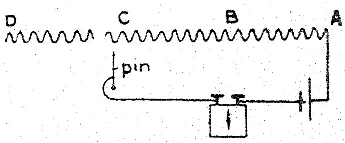


FIG. 57.

A convenient way of making contact with an insulated wire is to take a turn or two of the wire from the detector round an ordinary pin, then make contact by piercing the insulation with the pin point. This avoids cutting the insulation off the wire to be tested.

A pocket voltmeter will answer the purpose of a detector for testing a circuit.

When tracing a circuit, for the circuit to be complete, you must be able to get back to the starting-point.

If speech is very indistinct on the telephone, or if you fail to make yourself heard, always resort to the buzzer,

and send the message by Morse. A message can usually be sent through a broken wire by this method.

The Morse alphabet on the buzzer is denoted by a short buzz representing a dot, and a long buzz a dash.

When talking into a telephone always talk slowly and distinctly, and in a moderate tone of voice, keeping your mouth about two or three inches from the microphone.

A copy of the message in writing, should always if possible be kept at both the sending and receiving stations. This will enable the culprit to be traced, if the message delivered is incorrect.

For testing a telephone battery, a pocket (watch type) voltmeter is of great value. Its scale should be graduated to at least three volts, then the two cells can be tested at once. If, when testing a two-cell battery, the reading is below two volts, test each cell again separately, perhaps only one of them is bad.

This type of voltmeter can be purchased from *Veritys, Ltd.*, from about *7s. 6d.*; they are largely used by motorists.

"Medhurst" Field Telephone

This instrument is carried in a leather case, and consists of a small ebonite frame, which contains the induction coil, buzzer, microphone, condenser, and necessary switches.

The microphone, *f*, is of the capsule type, its case, *h*, being screwed to the outside of the ebonite frame. The induction coil is of rather novel design, as one end of its iron core has secured to it a piece of iron, which is bent and brought around the outside of the coil, close to the other end of the core, and which, when magnetised, will have a north and south pole side by side. This arrangement enables the primary of the induction coil to act, and

take the place of a separate buzzer; an armature and adjusting screw being placed opposite the above-mentioned poles. There is a two-way switch, *k*, which, in one position, connects the battery to the buzzer circuit, and in the other to the speaking, or primary, circuit (Figs. 58, 59).

When signalling, the key *l* must be worked, and when speaking it must be pressed, and the switch *k* moved to speaking.

The condenser is connected to the line terminal, for use when tapping a telegraph circuit. It can be short circuited by a strip of metal, if necessary, as under some line conditions the condenser is better out of circuit. The battery, *q*, consists of two Obach dry cells, and is carried at one end of the leather case and covered with a leather flap. The line and earth terminals, L, E, are secured to the outside of leather case, and have connected to them, on the inside, two metal strips, *p*, that make rubbing contact with two similar strips fixed on the ebonite frame.

This enables the telephone to be removed from its case without disconnecting the line wires.

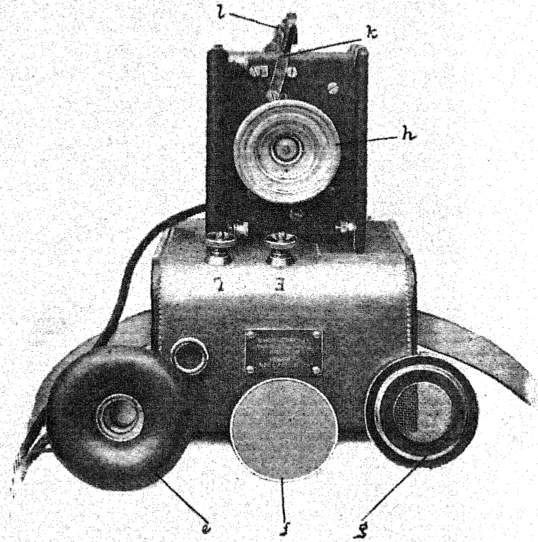
The switch *l*, when not pressed, short circuits the secondary of induction coil, causing the incoming call buzz to only pass round the receiver coils, which is an advantage.

The receiver, when not in use, rests on the leather flap that covers the cells.

Speaking from experience, excellent results have been obtained with this telephone. It was invented by Lieutenant Medhurst of the Australian Army, where it is greatly used.

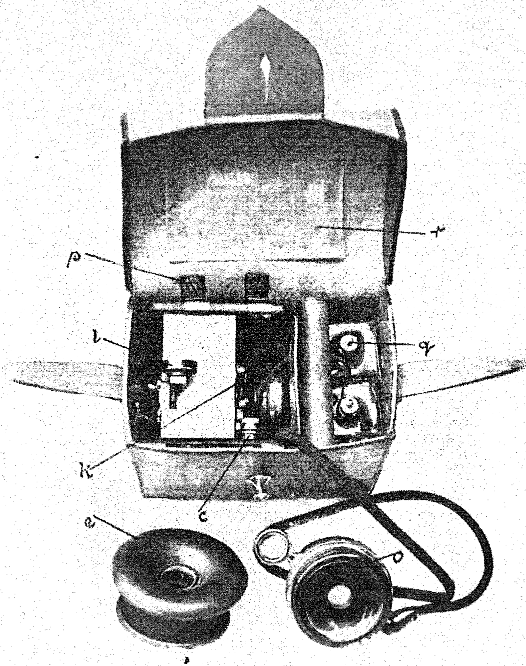
To use this telephone, it is not necessary to remove it from its case; all that is necessary is to open the lid, and speak into the case.

Fig. 59 shows the telephone in its leather case, and



E, Earth terminal
gh, Capsule case
p, Metal strip
L, Line terminal
k, Two-way switch

FIG. 58.



e, Ear cushion
l, Key
q, Battery
f, Microphone capsule
o, Receiver

FIG. 59.

Fig. 58 shows it removed from case, with microphone capsule removed.[1]

Weight of this telephone, complete in leather case, $4\frac{1}{2}$ lbs.

It is made by the *International Electric Company*, 55, *Redcross Street, London, E.C.* Price, net, £3 10*s*. each.

Field Work

Earth Connections.—An earth connection should, if possible, always be made in damp soil.

A pool of water or pond is an excellent earth connection, if time and material will permit you to make use of it.

The best earth connection one can obtain, is a water or gas pipe, as they run under the earth for a great distance.

If the soil is very dry and a tree is handy, for preference use the tree by driving an earth rod or metal peg into it, as the sap will make a good connection.

Before making a joint in a wire, always be sure and remove the covering for about one and a half inches, then join the bared ends and insulate, if time permits, with rubber tape.

If transmission of speech at any time breaks down, or if it is not clear, immediately resort to the buzzer, and send the message by Morse code.

If you fail to get a reply from the far station, immediately apply the rough tests to your own telephone, to see if it is in working order.

Always call up on the buzzer.

If you know the wire to be broken, and time does not permit of your going in search of the fault, try and get through on the buzzer, as this will very often work through a broken wire.

Always be careful to close the pressel switch when speaking into the microphone of a Portable C. and D.

[1] For circuit diagram, see p. 110.

Mk. I. telephone, and press the button in the microphone case when using the D. Mk. II. telephone.

Cross Talk.—It is very difficult to prevent cross talk or signalling when using earth returns, and if not guarded against, might lead to some confusion. For instance, a brigade of artillery (three batteries) A, B, and C, are each equipped with a Portable D. telephone, and are in telephonic communication with their Brigade Commander, D, who is also using a Portable D. telephone. When D calls up A on the buzzer, B and C will also, although somewhat weaker than if connected directly to this circuit,

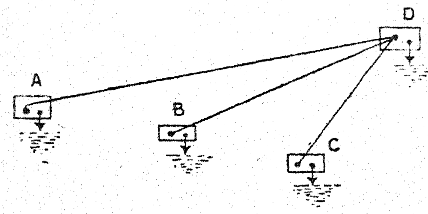


FIG. 60.

hear the buzz in their receiver (due to induction), and might, unless a prearranged code is determined upon, think the order was meant for them. This could be obviated by allowing the letter A to represent that battery, likewise B and C theirs; then, when D wished to send a message to A, he would, first of all, send the code letter A, and continue to do so until the battery A responded by sending this letter. The other two batteries, hearing this, would ignore it, and all other messages, unless preceded by their own code letter. If the brigade commander, to save time, wished to send his message to his three battery commanders, his telephone could send another code letter, which should be known by the battery telephonists to mean

that they are all to take the message, and, to let the telephonist at D know that they are ready, they should, immediately on hearing the signal, respond by sending their own code letter.

I have mentioned a letter and not a word as the code signal, to decrease, as much as possible, the time wasted in sending messages through.

The above is based on the assumption that the brigade commander is equipped with one telephone, with a three-way exchange attached, enabling him to speak to each or all at will, as used in the German army.

Using three separate telephones does not overcome this defect.

Cross talk can be partially overcome by keeping the line wires a good distance apart.

Crook sticks are used to place the wire on to trees, where they are available, to carry it across roads. If the wire cannot be hung clear of vehicles it should be buried in a shallow channel.

To tap a field telephone wire, connect a telephone receiver between the wire and earth, when the conversation will be heard.

Line Faults

There are usually two kinds of line faults when using field telephone wire with earth return, namely, a break and a short circuit. Both can very often be found by sending out a man to examine it, who should let the wire pass through his hand on the way. If it cannot be located in this way, apply the following tests:—

Break.—If you fail to hear the distant station, assuming that both telephones are in order, there is a break in the line somewhere. Connect the two-cell battery in your telephone directly between the line wire and earth, and proceed along the line with a detector, which should have

one of its terminals connected to an earth pin, and the other to an ordinary pin. Put the earth pin in the ground, and pierce the insulation of the wire at different places along the line, noting roughly the deflections. On obtaining no deflection, you will know that the fault lies between your present position and the point at which you last got a deflection, such as A and B in Fig. 61.

By a system of "bracketing" you can arrive at the exact spot, or by pulling on the wire between the two

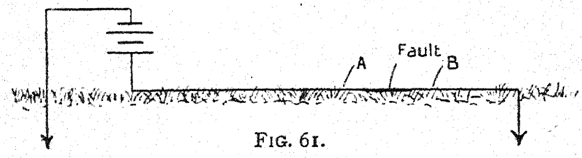


FIG. 61.

points mentioned; as the wire is broken the insulation will snap or stretch, and disclose the fault.

Short Circuit.—In the case of a short circuit, which would usually be caused by a wheel passing over a wire, pressing it into the earth and removing the insulation, or perhaps cutting the wire in two (as shown in Fig. 62), and pressing boths ends into the earth.

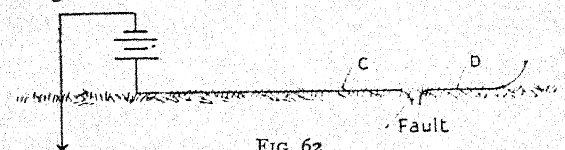


FIG. 62.

In this case the signals heard would be faint, especially if the ground is damp. The quickest way to locate this fault is to send a man out to examine it, passing the wire through his hand on the way. If the insulation is stripped, as a temporary measure, support the wire with stones to keep the defective part off the ground.

Joining a Wire.—To make a simple twist joint in a telephone wire, the insulation should be carefully cut off for about one inch and a half, and the wires scraped clean with a penknife or piece of emery cloth. Separate the wires if they are twisted together, and lay them side by side, then hold the ends at an angle to each other, and twist them by half turns, each end in succession, around each other four or five times, so that the turns lie close to each other. Carefully insulate it with a couple of layers of indiarubber tape.

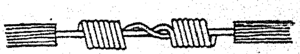


FIG. 63.

Fig. 63 represents a single wire joined in this way, but without the insulation.

Wire

Wire Gauge.—A cable or wire is usually designated by its standard wire gauge (S.W.G.) and the number of strands it contains.

Example.—A wire designated thus, 3/26, means that it is made up of three wires, the S.W.G. of each being 26.

The Mil.—Another way of comparing wires is by their diameter in mils., a mil. being equal to a thousandth of an inch. This is done by means of a gauge, which is graduated in thousandths of an inch. It is worked by means of a fine screw, and can easily measure to half a mil. This is a service store.

To find the S.W.G. of a wire, a gauge plate is used, which has a number of slots around its edge, with the gauge of the slot stamped near it.

If a wire is to be gauged, take one of the strands and find the smallest slot that the wire will enter without force. This will be the gauge of that particular wire. Some wires are made up of a number of strands of different gauge. In this case, each wire should be gauged separately.

Field telephone wire usually consists of several fine steel wires, varying in number from five to twelve, and insulated with specially prepared paper and cotton, steel wire being used for strength.

Morse Alphabet

A	· —	N	— ·
B	— · · ·	O	— — —
C	— · — ·	P	· — — ·
D	— · ·	Q	— — · —
E	·	R	· — ·
F	· · — ·	S	· · ·
G	— — ·	T	—
H	· · · ·	U	· · —
I	· ·	V	· · · —
J	· — — —	W	· — —
K	— · —	X	— · · —
L	· — · ·	Y	— · — —
M	— —	Z	— — · ·

Numerals

1	· — — — —	6	— · · · ·
2	· · — — —	7	— — · · ·
3	· · · — —	8	— — — · ·
4	· · · · —	9	— — — — ·
5	· · · · ·	0	— — — — —

The Parlyphone

Domestic Telephone.—A cheap form of telephone has been introduced which enables any existing house electric bell circuit to be utilised as a telephone circuit, without upsetting the working of the former. There are

two types of instruments: One for use in the kitchen, which would be fitted near the bell, and one for use in the drawing, dining, or any other room that you might require it in.

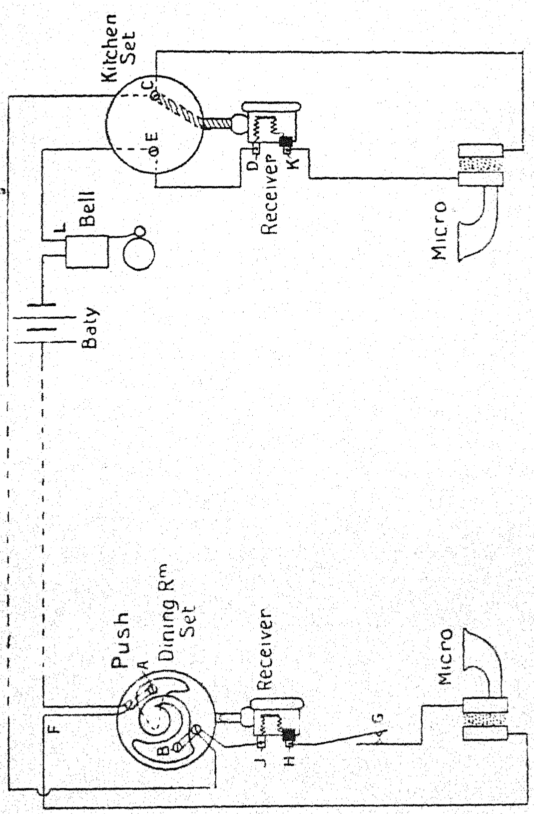


Fig. 64.

The latter type consists of an ordinary telephone receiver and microphone in series, the two wires coming from it are connected to the two springs of the bell push at

points A and B (see Fig. 64). Secured to the bell push is a hook for hanging it on, when not in use.

The kitchen type differs from the above by having a circular terminal block instead of a push, one of its terminals, C, having connected to it the metal hook that the telephone hangs on. It will also be noticed, on referring to the figure, that one of the receiver terminals is insulated from the case, and the other is common to it.

Circuit.—To call the kitchen, press push and the current will flow from positive of battery to A, B, C—as telephone is on hook, it gets from the hook to D, E—bell, to negative of battery. This rings bell.

To converse, remove telephone from hook, close pressel switch G, and a current will flow from positive of battery to A, F, through micro-carbons to G, H, receiver coils, J, B, C, through micro-carbons to K, receiver coils, E, bell coils (the current is now not strong enough to ring it), to negative of battery.

Action.—By talking into the microphone, the sound waves of the voice will cause the granulated carbons to vibrate, causing them to vary their contact with each other. This will vary the current in the circuit, and as it is a series circuit, will cause the magnetic field in the receiver to vary, which will vary its pull on the iron disc, causing it to vibrate. These vibrations are converted into sounds by the ear of the listener.

When conversation is finished, replace telephone on the hook.

The act of removing the kitchen telephone from its hook makes the current pass through its microphone and receiver; replacing it, short circuits microphone and receiver, as the current can get from C to hook, suspension ring to D, and away.

If the telephone is not on the hook at the kitchen end,

the bell will not ring, there being too much resistance in the circuit. It doesn't matter at the bell-push end, as the hook plays no part in the circuit, the current being made to go through the telephone at this end by pressing switch D. This should be released if you wish to ring the bell.

The two wires coming from the telephone of a drawing- or dining-room set, usually terminate in a two-pin plug, and all that is necessary to connect this to the bell push, is to insert it into a socket provided for it in the push.

To **instal a Parlyphone Set** to an existing bell circuit, disconnect the wire going to bell at L (Fig. 64), connect this to terminal C, connect a fresh piece of wire from E to L.

To connect dining-room push, disconnect the two wires inside old push, and remove it. Take new push and connect the wires previously disconnected to points A and B.

It is immaterial whether a house is wired with an indicator or not, as the indicator will work just the same.

All the bell pushes in a house can be fitted with the dining-room type.

A good method to adopt is to let one ring of the bell represent "I want you," and two rings "Use the telephone."

It is advisable to wait a few seconds after you have rung the bell before commencing conversation, to give the bell armature time to stop vibrating, or else you will hear it in your receiver, causing speech to be indistinct. If speech is indistinct at any time, slightly tap microphone.

Parlyphones can be obtained from *Verity, Ltd., King Street, Covent Garden, W.C.*:—

	s.	*d.*	
Dining-room type, including push, list price, from	8	0	each.
Kitchen type	7	0	„
Pushes	1	3	„

APPENDIX

SELF-INDUCTION--INDUCTIVE CAPACITY, ETC.

Induction

WHEN a current is started in a wire, circular lines of magnetic force (referred to on p. 26) are given out by the wire, whether it is insulated or not, and spread out through the air like sound waves, or the waves on the surface of water caused by dropping a stone into it, but at a very much greater velocity.

These circular magnetic lines of force will induce in the wire itself an E.M.F. in the opposite direction to the current causing it, tending to retard its flow. Should these lines of force encounter any other wire, they will also induce in it an E.M.F. to produce a current. On the stopping or weakening of the main or battery current, the lines of force will reverse their direction, as they will converge on the wire, causing an induced E.M.F. to be set up in the wire or wires, in the opposite direction to the first induced E.M.F.; its direction therefore is, in the case of the wire carrying the battery current, such, as to carry on the current after the circuit is broken.

From the above, it will be necessary to remember, that the induced current set up in the wire when the circuit is made, tends to impede the current causing it, and when the circuit is broken or the current decreased, tends to keep it flowing, and is termed "self-induction." The current induced in any other wires by the lines of force will be due to "induction."

If, instead of a straight wire, we consider it to be coiled into

a number of turns, this will greatly increase the self-induction, as the magnetic field of any one turn, will act upon every other turn in the coil. The self-induction can be further increased by winding the wire round soft iron, making an electro-magnet of it. This can be made evident by the vivid spark that is obtained, when a circuit containing an electro-magnet is broken. An electro-magnet therefore possesses inductance to a high degree, and will therefore offer great obstruction or *impedance* to rapidly varying or alternating currents, such as those given out and caused by talking into a telephone.

The unit of inductance is called the "Henry," and is the inductive effect caused, when the inducing current varies at the rate of 1 ampere per second, producing an E.M.F. of 1 volt. It is represented by the symbol "L."

Inductive Capacity

The statical inductive effects between wires vary according to the insulation between them ; from this it will be seen that the quality of the insulation which determines the intensity of statical induction between the wires, is termed its "inductive capacity." The inductive capacity of dry air is less than any other insulator, and is usually taken as unity.

The inductive capacity of	Resin is	1·7
,, ,, ,,	Manilla paper	1·8 to 2·5
,, ,, ,,	Paraffin paper	2·0
,, ,, ,,	Raw indiarubber	2·0
,, ,, ,,	Ebonite	2·3
,, ,, ,,	Vulcanised indiarubber	2·5
,, ,, ,,	Guttapercha	2·5
,, ,, ,,	Glass	3·0
,, ,, ,,	Mica	5·0

These values have to be carefully considered in the manufacture of telephone cables, and an insulation chosen which has the smallest inductive capacity, yet suitable for the case. Statical induction is very detrimental to telephone currents.

An example of this, is the large quantity of telephone cable now made which has the wires enclosed in loose paper tubes, depending principally for its insulation on the dry air between it and the paper tube.

Statical Capacity

When a current flows through a wire, it charges every part of the surface of it with a statical or stationary charge of electricity. This charge depends upon the surface area of the wire, how close it is to other wires, and the specific inductive capacity of the insulation intervening between the wires, and it has the effect of weakening the original current by abstracting from it, and also of weakening succeeding currents by opposing their growth. This is very detrimental on long lengths of cable, and it is on this account that speaking over more than a few miles of wire is not possible under ordinary conditions.

The capacity effect is small on overhead lines, the wires being wide apart and separated by air, which has the least inductive capacity.

The Condenser

Theoretically, a condenser consists of two conducting sheets, or plates of metal placed near each other, the space between them being filled with an insulating material. In order to get large sheets in a limited space, it is usual to interleave smaller sheets and connect alternate ones together; they are prevented from touching by sheets of paraffined paper or mica. Condensers used in telephones are made in this way, and consist of tinfoil sheets separated with paraffined paper. Fig. 65 represents a condenser of this form. The sheets of tinfoil are placed with their points projecting alternately; F are the even, and F′ the odd numbers. They are joined together at the points where they project beyond the paper P.

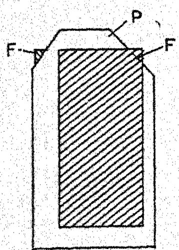


FIG. 65.

Action.—In order to understand thoroughly the action of a condenser, it is necessary to have a knowledge of statical electricity, so that I intend here to give a practical explanation of it, when used with a telephone.

In some telephones a condenser is joined in series with one of the line terminals, L′, as in Fig. 66, an advantage of this being, that it can be used for tapping or utilising a telegraph wire without in any way interfering with its signals, as the latter uses a direct, or battery current, which will not enter the telephone, as the condenser acts as a break to such a current.

If a small alternating current generator (such as that used in a telephone) be connected to the line terminal LL′ of a telephone with condenser (Cr, Fig. 66), on turning the handle of the

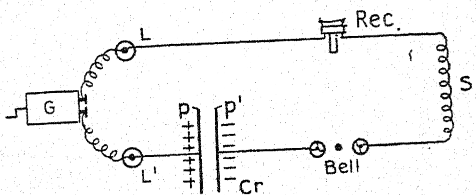


FIG. 66.

generator, a current will first enter by, say, L′, and charge the plate P with a stationary charge of positive electricity; P′ being in connection with the other terminal of the generator will have an equal but opposite, or negative charge, as shown. The next flow of current from the generator will enter by the terminal L, and charge the plate P′ with a positive current; but, before this can take place, the positive charge on P has to discharge itself, and in doing so, passes through the bell coils, ringing the bell; when the current again enters by L′, as P′ now has a positive charge, it will, before P can be given a positive charge, have to discharge itself and again ring the bell; so that as long as currents are altering their direction, they will also be passing to and fro from both condenser plates.

It will thus be seen that magneto-electric ringing currents may be readily transmitted through a condenser. If, instead of

a generator, another telephone be connected to LL′, the speaking current, being alternating, will actuate the condenser in the same way and, as they will flow through the receiver, speech will be heard. The more rapidly the current alternates, the more efficient is the condenser.

In an ordinary telephone magneto-generator, the current alters its direction about 20 times per second.

The alternations of a speech wave are about 800 per second.

The unit of statical electricity is named the "farad," and as this is too large for practical purposes, a sub-unit called the "microfarad" is used, it being one-millionth part of a farad.

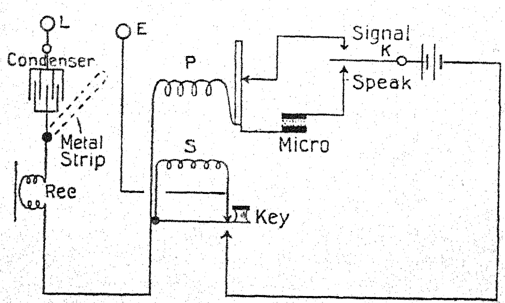


FIG. 67.—Circuit diagram of Medhurst telephone (see p. 94).

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